(Un)expected Monetary Policy Shocks and Term premia: A Bayesian Estimated Macro-Finance Model

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Research Question

What are the quantified effects of monetary policy on the term structure?

- Empirical literature has yet to reach a definitive conclusion
- Linear structural models do not go beyond expectation hypothesis
- Nonlinear structural models face significant quantitative constraints

⇒ To answer this question, we need a structural model which

- successfully explains macro and finance facts simultaneously
- allowing us to study different monetary policy tools

⇒ We analyze monetary policy in a workhorse New Keynesian model

- macros and yield curve estimated jointly with Bayesian likelihood
- underlying macro risks generate upward sloping yield via no-arbitrage pricing of risk

This paper estimates a structural model

...with time-variation in risk premia

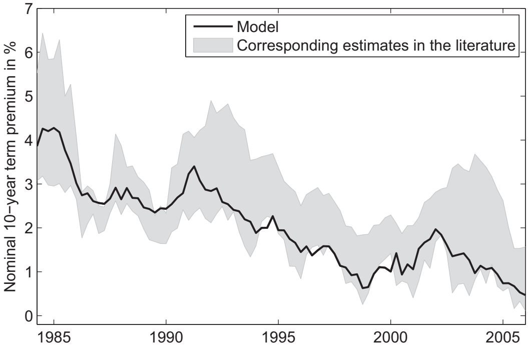


Figure : Model implied 10-year nominal term premium (black line) and range of corresponding estimates in the literature (gray area).

Main findings I

- Predicts upward sloping nominal and real yield curves
- Real risk premia play important role
  - → 70% real risk, 30% inflation risk
- Historical smoothed time series for bonds and risk premia
  - → comparable to empirical estimates

Some empirical evidence

Hanson and Stein (2015): Monetary news has strong effects on forward real rates mostly reflecting change in the real term premia.

Nakamura and Steinsson (2017): Monetary news has small effects on risk premia. Qualitative impact on nominal term premium depends on maturity

Abrahams et al. (2016): Confirms findings from Hanson and Stein (2015); nominal term premium increases after increase of policy rate (see also Gertler and Karadi (2015))

Crump et al. (2016): Contrarily, decrease of nominal term premium after increase of policy rate

$\Longrightarrow$ Different samples, identification approaches, do not distinguish btw. forward guidance, systematic component, or shock to residual (see Ramey (2016))

Main findings II

- A standard MP shock has small effects on term premium (see Nakamura and Steinsson (2017))
- A shock to the systematic component of MP has larger and long lasting effects on term premium (see Hanson and Stein (2015))
- Unconditional forward guidance increases real and inflation risk of long-term bonds

→ Nominal term premium increases (see Akkaya et al. (2015)) which dampens the expansionary effect

Model overview

- general equilibrium macro-finance model (e.g. Rudebusch and Swanson (2012); Andreasen et al. (2017))
  - closed-economy New-Keynesian DSGE
  - nominal and real frictions
  - external habit formation
  - long-run nominal and real risk
  - price stickiness (Calvo)
  - monetary policy characterized by Taylor-rule
- consumption-based asset pricing (arbitrage-free, frictionless)

$\Rightarrow$ we use recursive preferences (Epstein-Zin-Weil) to disentangle intertemporal elasticity of substitution and risk aversion

Monetary Policy

Taylor-type policy rule:

$$4r_t^f = 4\cdot\rho_R r_{t-1}^f + (1-\rho_R)\left(4\bar{r}^{real} + 4\log\pi_t + \eta_y \log\left(\frac{y_t}{z_t^+\bar{y}}\right)\right.$$
$$\left. + \eta_\pi \log\left(\frac{\pi_t^4}{\pi_t^*}\right)\right) + \sigma_m \epsilon_{m,t}$$

Time-varying inflation target (long–run nominal risk):

$$\log\pi_t^* - 4\log\bar{\pi} = \rho_\pi\left(\log\pi_{t-1}^* - 4\log\bar{\pi}\right) + 4\zeta_\pi\left(\log\pi_{t-1} - \log\bar{\pi}\right) + \sigma_\pi\epsilon_{\pi,t}$$

Bond pricing

Nominal zero-coupon bond prices ($p_t^{(0)} = 1$ and $\hat{p}_t^{(0)} = 1$):

Risky: $p_t^{(n)} = E_t\left[M_{t,t+1} p_{t+1}^{(n-1)}\right]$, Risk neutral: $\hat{p}_t^{(n)} = \left(R_t^f\right)^{-1} E_t\left[\hat{p}_{t+1}^{(n-1)}\right]$

The continuously compounded return of n-period bond is defined as:

$$r_t^{(n)} = -\frac{1}{n} \log p_t^{(n)}$$

Term premium: difference between the risky and risk-neutral returns

$$TP(n) = \frac{1}{n}\left(\log \hat{p}_t^{(n)} - \log p_t^{(n)}\right) = -\frac{1}{n} E_t \sum_{j=0}^{n-1} e^{-r_{t,t+j+1}} cov_{t+j}\left(M_{t+j+1}, p_{t+j+1}^{(n-j-1)}\right)$$

Higher-order solution technique (see Meyer-Gohde (2016))

- We adjust point and slope for risk out to second moments
- capture both constant and time-varying risk premium
- risk-sensitive linear approximation around the ergodic mean

⇒ non-certainty-equivalent approximation, but linear in states

⇒ This allows us to use the **standard** set of tools for estimation and analysis of linear models, without limiting the approximation to the certainty-equivalent approximation around the deterministic steady state.

Linear Non-Certainty Equivalent Approximation

- For the policy function $y_t = g(y_{t-1}, \varepsilon_t, \sigma)$
- Reorganize partial derivatives at deterministic steady state

$$y_{y^i,\varepsilon^j,\sigma^k}\Big|_{y=\bar{y},\varepsilon=0,\sigma=0}$$

- to construct approximations (in σ) of
  - ergodic mean

$$y(\sigma) \equiv E\left[g(y_{t-1}, \sigma\varepsilon_t, \sigma)\right] = E\left[y_t\right]$$

  - derivatives at the ergodic mean

$$y_y(\sigma) \equiv g_y(y(\sigma), 0, \sigma)$$
$$y_\varepsilon(\sigma) \equiv g_\varepsilon(y(\sigma), 0, \sigma)$$

- Linear approximation at the (approximated) ergodic mean

$$y_t \simeq y(\sigma) + y_y(\sigma)(y_{t-1} - y(\sigma)) + y_\varepsilon(\sigma)\varepsilon_t$$

▸ Accuracy

Estimation

- We estimate the model using macro and financial data from 1983:Q1 until 2007:Q4
  - → Choice of time span driven by financial crisis starting in 2008 and change of systematic monetary policy at beginning of 1980s
  - **Macro data:** real GDP growth (Δy_t), real consumption growth (Δc_t), real investment growth (ΔI_t), inflation (π_t), policy rate (R_t, 3m T-bill)
  - **Survey data:** 1q and 4q-ahead expected short rates ($E\left[R_{t,t+1}\right]$,$E\left[R_{t,t+4}\right]$)
  - **Financial data :** US Treasury yields with 1year, 2year, 3year, 5year, and 10year maturity from Adrian et al (2013)
- We use an endogenous prior approach (Del Negro and Schorfheide, 2008) to explain key macro and asset pricing facts jointly ▸ Details
- Posterior estimates of parameters in line with other New Keynesian and macro-finance studies ▸ Estimates

Predicted nominal yield curve

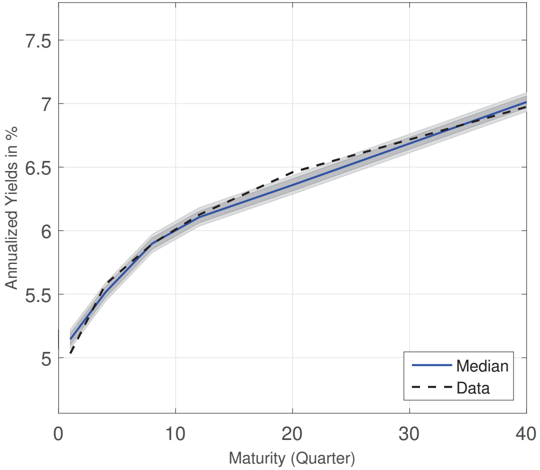
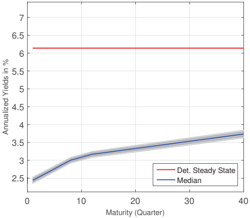


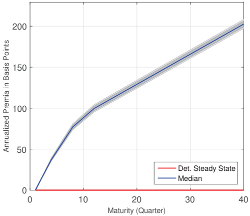
Figure : Nominal Yield Curve

▸ Why is the nominal yield curve upward sloping?

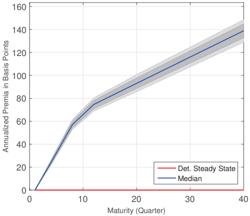
Predicted term structure of interest rates



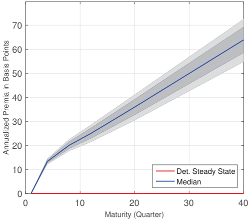
(a) Real Yield Curve



(b) Nominal Term Premium



(c) Real Term Premium



(d) Inflation risk premium

▸ Why is the real yield curve upward sloping?

Predicted 1st and 2nd moments: macro variables

Name	Data		Model	
	Mean	S.d.	Mean	S.d.
GDP growth	0.540	0.593	**0.540**	0.803
		[0.515, 0.764]		[0.761, 0.838]
Consumption growth	0.610	0.435	**0.540**	0.559
		[0.383, 0.515]		[0.528, 0.587]
Investment growth	0.620	2.096	**0.620**	2.292
		[1.796, 2.744]		[2.120, 2.438]
Annualized inflation	2.496	1.022	2.469	1.198
		[0.840, 1.493]	[2.418, 2.515]	[1.136, 1.254]
Annualized policy rate	5.034	2.069	5.144	2.861
		[1.521, 3.927]	[5.070, 5.222]	[2.733, 3.026]

Table : Predicted first and second moments of selected macro variables. Bold moments are calibrated.

Historical fit: 10-year nominal term premium

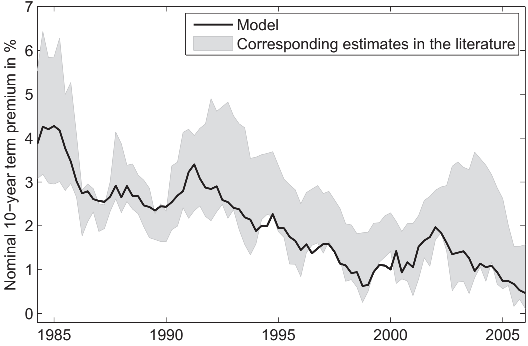


Figure : Model implied 10-year nominal term premium (black line) and range of corresponding estimates in the literature (gray area).

Historical fit: 10-year nominal term premium

	Bernanke et al.	Kim and Wright	Adrian et al.	S.d.
Bernanke et al. (2004)	1.000			1.294
Kim and Wright (2005)	0.976	1.000		0.981
Adrian et al. (2013)	0.817	0.891	1.000	1.033
Model	0.904	0.940	0.868	0.943

Table : Correlations among four measures of the 10-year term premium from 1984:q1-2005:q4. The last column presents the standard deviation over the sample.

Historical fit: 10-year real rate

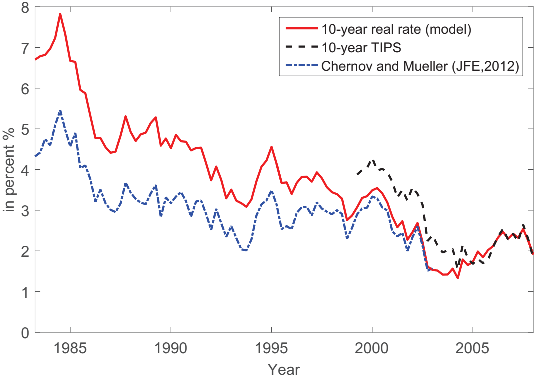


Figure : Model implied 10-year real rates (red solid), 10-year TIPS of Gürkaynak et al. (2010) (black dashed), and 10-year real rate of Chernov and Mueller (2012)(blue dash-dotted).

Historical fit: 10-year break-even & Inflation risk premium

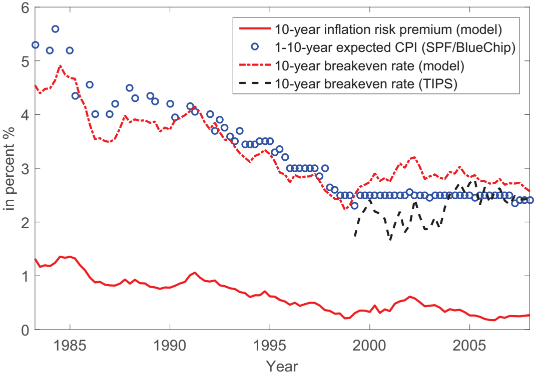
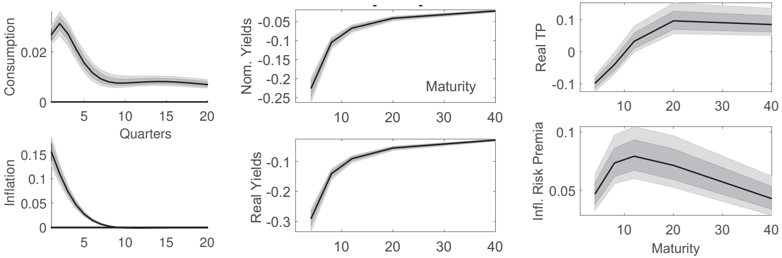


Figure : Model implied 10-year break-even inflation rate (red dash-dotted) solid), 10-year break-even inflation rate of Gürkaynak et al. (2010) (black dashed), model implied 10-year inflation risk premium (red solid), 1 to 10-year average expected inflation from SPF and BlueChip (blue circle).

Monetary policy shock (-50bps)



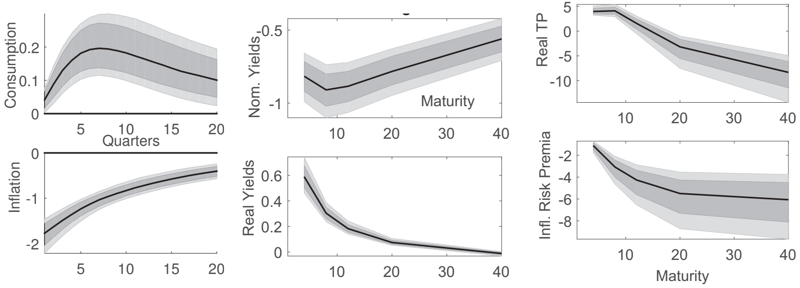
(a) Dynamic Macros (b) Impact Yields (c) Impact Premia

Differing effects on the term premia

- Expansionary effect, real and nominal yields fall
- Consumption initially rises relative to habit, later falls
- Hence, insurance-like negative for short, positive real TP for longer maturities

Effect on yield curve is falling in maturities

Inflation target shock (-50bps)



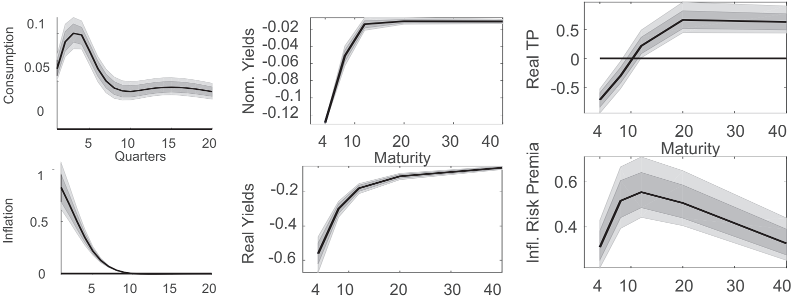
(d) Dynamic Macros (e) Impact Yields (f) Impact Premia

Again, differing effects on the term premia

- Initial contractionary effect, real yields rise as HHs draw down precautionary savings to finance consumption and habit
- Consumption initially rises relative to habit, later falls
- Hence, positive for short, insurance-like negative real TP for longer maturities

The entire nominal yield curve is shifted downward

Forward guidance (-50bps in 4 quarters)



(g) Dynamic Macros (h) Impact Yields (i) Impact Premia

Large expansionary effect with a significant rise in inflation

- Inflationary effects reduce response of nominal yield curve
  - directly over the expectations hypothesis and
  - both inflation risk and real TP rise for all but short maturities
  - → total nominal TP nearly 1 bp for all but shortest maturities
- Only the very short end of the yield curve moves

Rise in real TP dampens expansionary effect ▸ Details of Implementation

Conclusion

- estimated DSGE model with time-varying risk premia
- in line with empirical facts about the term structure
- structural model well-suited to investigate effects of monetary policy on risk premia
- shocks to the Taylor-rule have small effects on risk premia
- shocks to systematic component of monetary policy much more long-lasting and therefore larger effects on term premia
- forward guidance increases risk premia [→] especially for longer maturities

References I

ABRAHAMS, M., T. ADRIAN, R. K. CRUMP, E. MOENCH, AND R. YU (2016): "Decomposing real and nominal yield curves," Journal of Monetary Economics, 84, 182–200.

ADRIAN, T., R. K. CRUMP, AND E. MOENCH (2013): "Pricing the term structure with linear regressions," Journal of Financial Economics, 110, 110–138.

AKKAYA, Y., R. GÜRKAYNAK, B. KISACIKOĞLU, AND J. WRIGHT (2015): "Forward guidance and asset prices," IMES Discussion Paper Series, E-6.

ANDREASEN, M. M., J. FERNÁNDEZ-VILLAVERDE, AND J. F. RUBIO-RAMÍREZ (2017): "The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications," Review of Economic Studies, forthcoming.

BACKUS, D. K., A. W. GREGORY, AND S. E. ZIN (1989): "Risk premiums in the term structure : Evidence from artificial economies," Journal of Monetary Economics, 24, 371–399.

References II

Bernanke, B. S., V. R. Reinhart, and B. P. Sack (2004): "Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment," Brookings Papers on Economic Activity, 35, 1–100.

Chernov, M. and P. Mueller (2012): "The term structure of inflation expectations," Journal of Financial Economics, 106, 367–394.

Crump, R. K., S. Eusepi, and E. Moench (2016): "The term structure of expectations and bond yields," Staff report, FRB of NY.

Del Negro, M., M. Giannoni, and C. Patterson (2015): "The forward guidance puzzle," Staff Reports 574, Federal Reserve Bank of New York.

Del Negro, M. and F. Schorfheide (2008): "Forming priors for DSGE models (and how it affects the assessment of nominal rigidities)," Journal of Monetary Economics, 55, 1191–1208.

den Haan, W. J. (1995): "The term structure of interest rates in real and monetary economies," Journal of Economic Dynamics and Control, 19, 909–940.

References III

Gertler, M. and P. Karadi (2015): "Monetary policy surprises, credit costs, and economic activity," American Economic Journal: Macroeconomics, 7, 44–76.

Gürkaynak, R. S., B. Sack, and J. H. Wright (2010): "The TIPS Yield Curve and Inflation Compensation," American Economic Journal: Macroeconomics, 2, 70–92.

Hanson, S. G. and J. C. Stein (2015): "Monetary policy and long-term real rates," Journal of Financial Economics, 115, 429–448.

Hördahl, P., O. Tristani, and D. Vestin (2008): "The Yield Curve and Macroeconomic Dynamics," Economic Journal, 118, 1937–1970.

Kim, D. H. and J. H. Wright (2005): "An arbitrage-free three-factor term structure model and the recent behavior of long-term yields and distant-horizon forward rates," Finance and Economics Discussion Series 2005-33, Board of Governors of the Federal Reserve System (U.S.).

References IV

LASÉEN, S. AND L. E. SVENSSON (2011): "Anticipated Alternative Policy Rate Paths in Policy Simulations," International Journal of Central Banking.

MEYER-GOHDE, A. (2016): "Risk-Sensitive Linear Approximations," mimeo, Hamburg University.

NAKAMURA, E. AND J. STEINSSON (2017): "High frequency identification of monetary non-neutrality: The information effect," Quarterly Journal of Ecnomics, forthcoming.

PIAZZESI, M. AND M. SCHNEIDER (2007): "Equilibrium Yield Curves," in NBER Macroeconomics Annual 2006, Volume 21, National Bureau of Economic Research, Inc, NBER Chapters, 389–472.

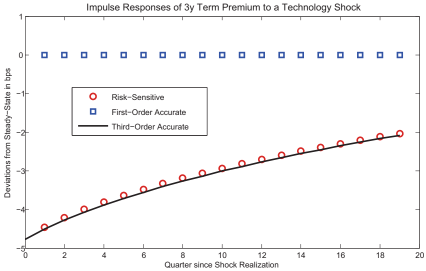
RAMEY, V. A. (2016): "Macroeconomic Shocks and Their Propagation," in Handbook of Macroeconomics, ed. by J. B. Taylor and H. Uhlig, Elsevier, vol. 2, chap. 2, 71–162.

References V

RUDEBUSCH, G. D. AND E. T. SWANSON (2012): “The Bond Premium in a DSGE Model with Long-Run Real and Nominal Risks,” American Economic Journal: Macroeconomics, 4, 105–43.

WACHTER, J. A. (2006): “A consumption-based model of the term structure of interest rates,” Journal of Financial Economics, 79, 365–399.

Accuracy of Approximation



- Risk-sensitive not as accurate as full third-order perturbation
- But does captures the third-order dynamics remarkably well ...
- ...even though the solution is linear in states and shocks

Return

Endogenous prior (Del Negro and Schorfheide, 2008)

posterior:

$$
\begin{aligned}
p(\theta|X,S,F) &\propto p(\theta|F,S) \times p(X|\theta) \\
&\propto p(\theta) \times p(F|F_m(\theta)) \times p(S|\theta) \times p(X|\theta)
\end{aligned}
$$

- $p(\theta)$ initial set of prior
- $p(F|F_m(\theta))$ quasi-likelihood related to first moments we have a priori information about
- $p(S|\theta)$ likelihood related to second moments we have a priori information about, here variance of $\Delta y, \Delta c, \Delta I, \pi, R$ (see Christiano, Trabandt and Walentin, 2011)
- $p(X|\theta)$ likelihood related to data

Endogenous prior - first moments

- Let $F_m(\theta)$ vector-valued function which relates DSGE model parameters θ and first moments of interest

$$F = F_m(\theta) + \eta$$

- F vector of measures of first moments:
  - average of inflation, level, slope and curvature of nominal yield curve
  - example: $\bar{\pi}^{US} = E[\pi_t; \theta] + \eta_\pi$

  $\rightarrow$ $\pi^{SS} \neq E[\pi_t; \theta]$ because of precautionary motive (see, e.g. Tallarini, 2000)
- η measurement error, which are independently and normally distributed
- $p(F|F_m(\theta)) = \exp\left(T/2(F - F_m)' \Sigma_\eta^{-1}(F - F_m)\right)$

Return

Selected parameter estimates

Name	Mode	Mean	5%	95%
Relative risk aversion	89.860	91.427	75.581	108.489
Calvo parameter	0.853	0.855	0.843	0.866
Habit formation	0.685	0.679	0.614	0.741
Intertemporal elas. substitution	0.089	0.089	0.077	0.101
Steady state inflation	1.038	1.034	0.981	1.091
Interest rate smoothing coefficient	0.754	0.752	0.718	0.786
Interest rate inflation coefficient	3.124	3.164	2.839	3.491
Interest rate output coefficient	0.156	0.159	0.114	0.204

Table : Posterior stats. Post. means and parameter dist.: MCMC, 2 chains, 100,000 draws each, 50% of the draws used for burn-in, and draw acceptance rates $\approx 1/3$.

Return

Calibration

Description	Symbol	Value
Technology trend in percent	$\bar{z}^+$	0.54/100
Investment trend in percent	$\bar{\Psi}$	0.08/100
Capital share	α	1/3
Depreciation rate	δ	0.025
Price markup	$\theta_p/(\theta_p - 1)$	1.2
Price indexation	ξ_p	0
Discount factor	β	0.99
Frisch elasticity of labor supply	FE	0.5
Labor supply	$\bar{l}$	1/3
Ratio of government consumption to output	$\bar{g}/\bar{y}$	0.19

Table : Parameter calibration.

Model fit

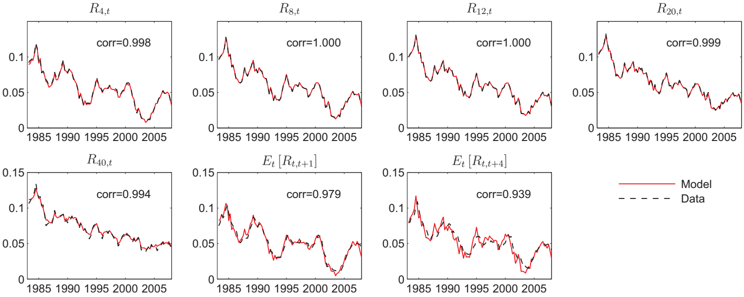


Figure : Observed and model implied nominal returns of treasury bills and returns of expected short rates.

Why is the nominal yield curve upward sloping?

- Backus et al. (1989), den Haan (1995)
- in a recession short rates are low, so long-term bonds should have higher price

$\longrightarrow$ bonds should carry an insurance-like premium

- But: in a recession induced by supply shocks $\rightarrow$ inflation goes up

$\longrightarrow$ real value of the bond decreases

$\longrightarrow$ dominant role of supply shocks explain slope (Piazzesi and Schneider, 2007)

$$TP^{(n)} = -\frac{1}{n} E_t \sum_{j=0}^{n-1} e^{-r_{t,t+j+1}} cov_{t+j}\left(M_{t+j+1}, p_{t+j+1}^{(n-j-1)}\right)$$

▸ Return

Why is the real yield curve upward sloping?

- Following Wachter (2006) and Hördahl et al. (2008)
- habit formation induces positive autocorrelation in consumption growth
- households will seek to maintain their habit in the face of a slow-down in consumption

→ drawing down precautionary savings → long-term bond price falls

→ negative correlation between stochastic discount factor and bond prices

$$TP^{(\$,n)} = -\frac{1}{n} E_t \sum_{j=0}^{n-1} e^{-r_{t,t+j+1}} cov_{t+j}\left(M^{\$}_{t+j+1}, p^{(\$,n-j-1)}_{t+j+1}\right)$$

▸ Return

Modelling forward guidance

Sequence of anticipated policy shocks to model forward guidance

- Laséen and Svensson (2011), Del Negro et al. (2015)

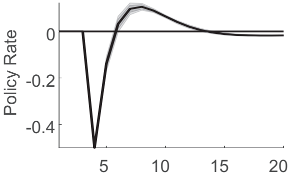
Resulting in the following change to the standard interest rate rule:

$$R_t = R(R_{t-1}, \pi_t, Y_t) + \sum_{k=0}^{K} \epsilon_{t,t+k}$$

where $\epsilon_{t,t+k}$ is a shock known to agents at time t, but realized at time $t+k$.

As our equilibrium system is linear in states,

- Finding the anticipated shocks to condition the interest rate path
- simply requires solving a square linear system of dimension k



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