Bond premia and monetary policy over 40 years

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Motivation

- A number of empirical observations linked to the yield curve have been seen as puzzling: stubbornly high long-term yields in the 1980s; the "conundrum" of low yields early in the new millennium; the failure of the EH

- Movements in term premia may provide an explanation (finance) - but not clear what fundamental factors drive these premia

- Can other influences help explain such puzzles? imperfect credibility? (macro)

- We examine relationships between yields/premia and the macroeconomy using an estimated macro-finance DTSM; we study the role of allowing investors to learn about the CB’s objectives (finance & macro)
US 10-year bond yield and inflation
Motivation

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- Can other influences help explain such puzzles? imperfect credibility? (macro)

- We examine relationships between yields/premia and the macroeconomy using an estimated macro-finance DTSM; we study the role of allowing investors to learn about the CB’s objectives (finance & macro)
Outline

- Methodology / model

- Data and estimation method

- Results: model fit; premia estimates; determinants of premia

- Results: IRs; the role of imperfect policy credibility

- Results: the expectations puzzle; Campbell-Shiller tests
Methodology

- Macro dynamics derived from a "structural," empirically plausible model

- Allow for imperfect information/credibility w.r.t. the CB’s objective (e.g. Erceg & Levin ‘03; Gürkaynak ‘05; Koziki & Tinsley ‘05)

- Include relevant information on expectations: survey data

- No-arbitrage restrictions added to the macro structure: arbitrage-free yields consistent with macro dynamics (Ang & Piazzesi ‘03; HTV ‘06)

→ Macro-based interpretations of term structure dynamics, including dynamic responses of yields and premia to structural shocks; can study effects of learning
The model: macro

inflation: \( \pi_t = \mu_\pi E_t [\pi_{t+1}] + (1 - \mu_\pi) \pi_{t-1} + \delta_x x_t + \eta_{\pi,t} \)

output gap: \( x_t = \mu_x E_t [x_{t+1}] + (1 - \mu_x) x_{t-1} - \zeta_r (r_t - E_t [\pi_{t+1}]) + \eta_{x,t} \)

short rate: \( r_t = \bar{r} + (1 - \rho) [\beta (\pi_t - \pi^*_{p,t}) + \gamma x_t] + \rho r_{t-1} + \pi^*_{q,t} \)

target: \( \pi^*_{p,t} = \phi_p \pi^*_{p,t-1} + \varepsilon_{p,t} \)

\[ \eta_{\pi,t} = \phi_\pi \eta_{\pi,t-1} + \varepsilon_{\pi,t} \]

\[ \eta_{x,t} = \phi_x \eta_{x,t-1} + \varepsilon_{x,t} \]
The model: allowing for imperfect policy credibility

Agents can only observe a linear combination of the target and the policy shock, not the individual components (as in Erceg & Levin, 2003)

actual policy rule: \( r_t = \bar{r} + (1 - \rho) \left[ \beta (\pi_t - \pi^*_p,t) + \gamma x_t \right] + \rho r_{t-1} + \pi^*_q,t \)

Agents know the structure of the economy & parameters; agents obtain filtered values using available information

perceived policy rule: \( r_t = \bar{r} + (1 - \rho) \left[ \beta (\pi_t - \hat{\pi}^*_p,t|t) + \gamma x_t \right] + \rho r_{t-1} + \hat{\pi}^*_q,t|t \)
Key ingredients of the model

Macro: model

\[
\begin{bmatrix}
X_1, t+1 \\
EtX_2, t+1
\end{bmatrix} = J \begin{bmatrix}
X_1, t \\
X_2, t
\end{bmatrix} + Sr_t + \begin{bmatrix}
v_{1,t} \\
0
\end{bmatrix}
\]

\[r_t = -G \begin{bmatrix}
X_1, t \\
X_2, t
\end{bmatrix}\]

Macro: solution

\[X_2, t = CX_1, t\]

\[X_{1,t+1} = MX_1, t + v_{1,t+1}\]

\[r_t = \Delta'X_1, t\]

Finance: assumption on stochastic discount factor / MPR

\[Y_t = A + B'X_1, t\]
The model: market prices of risk

Market prices of risk determined empirically as affine functions of the states

\[ \lambda_t = \lambda_0 + \lambda_1 \times States_t \]

We use

\[ \lambda_t = \begin{pmatrix} \lambda_{01} \\ \lambda_{02} \\ \lambda_{03} \\ \lambda_{04} \end{pmatrix} + \begin{pmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} & \lambda_{14} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} & \lambda_{24} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} & \lambda_{34} \\ \lambda_{41} & \lambda_{42} & \lambda_{43} & \lambda_{44} \end{pmatrix} \begin{pmatrix} \hat{\pi}_{p,t} \\ \hat{\pi}_{q,t} \\ \eta_{\pi,t} \\ \eta_{x,t} \end{pmatrix} \]

Each row of \( \lambda_t \) determines the price of risk associated with each of the states; these vary over time with the level of the states.
The model: yields depend on perceived values of the states

- Agents’ expectations about future inflation, policy rates, etc. are based on their perceptions of the target and the policy shock, rather than the true values

- Bond yields therefore also depend on the perceived state variables: in general different from yields under full information
Estimation

- Bayesian Maximum Likelihood using Kalman Filter; we exploit prior information on structural economic relationships

- Survey data information (inflation and short-term interest rate) explicitly included in the estimation

- Estimation using simulated annealing to reduce risk of local maxima
Data: US, Q2 1967 - Q4 2007

- Macro data: q-o-q CPI inflation (Cleveland Fed 16% trimmed mean)
- Macro data: output gap - log-GDP in deviations from CBO estimate of potential
- Bond yields: 8 maturities of zero-coupon rates from 1-q to 10-y (Fed Board)
- Survey data: CPI inflation in the next year/10 years; 3-m rate 2/4 quarters ahead (SPF)
**Results**: Parameter estimates

**inflation**: $\pi_t = 0.91 E_t [\pi_{t+1}] + (1 - 0.91) \pi_{t-1} + 0.07 x_t + \eta_{\pi,t}$

**output gap**: $x_t = 0.67 E_t [x_{t+1}] + (1 - 0.67) x_{t-1} - 0.01 (r_t - E_t [\pi_{t+1}]) + \eta_{x,t}$

**short rate**: $r_t = 0.01 + (1 - 0.89) \left[1.20 \left( \pi_t - \pi_{p,t}^* \right) + 0.31 x_t \right] + 0.89 r_{t-1} + \pi_{q,t}^*$

**target**: $\pi_{p,t}^* = 0.99 \pi_{p,t-1} + \varepsilon_{p,t}$

$\eta_{\pi,t} = 0.79 \eta_{\pi,t-1} + \varepsilon_{\pi,t}$

$\eta_{x,t} = 0.73 \eta_{x,t-1} + \varepsilon_{x,t}$
**Results**: Perceived inflation target
10y yield: actual and EH consistent model-implied
Estimated 10y term premium and error
10-year term premium and components
Actual and perceived target responses to a target shock
Response of 10y yield and term premium to a target shock
Response of 10y yield and term premium to a target shock: Full information
Response of 10y yield and term premium to an output shock
Campbell-Shiller regressions

\[ y_{t+1}^{n-1} - y_t^n = \text{const.} + \phi_n \frac{(y_t^n - r_t)}{(n-1)} + \text{residual} \]

- Expectations hypothesis: \( \phi_n = 1 \)

- Empirical evidence: \( \phi_n \neq 1 \) and typically negative
• Dai and Singleton (2002) - *LPY*: a DTSM should be able to get closer to the empirical CS parameters than the EH
Model-implied Campbell-Shiller parameters

![Graph showing model-implied Campbell-Shiller parameters with various lines and markers representing different data series.](image-url)
How much does imperfect credibility / learning help?
Conclusions

- Using a macro-finance model that allows for imperfect policy credibility, we identify stylised facts linking macro conditions and the evolution of yields and term premia over 40 years of US data.

- Monetary policy is the main determinant of premia in long-term nominal bonds through agents’ perceptions of the Fed’s objectives.

- Increases in the perceived target raise term premia; premia are also sensitive to the business cycle, and more so when the target is perceived to be high.

- Imperfect policy credibility can account for only a fraction of the expectations puzzle; time-varying premia are needed to fully account for the EP.
Extra Slides
Table 1: Parameter estimates

(Sample period: Q2:67 – Q4:07)
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Mean</th>
<th>St.err.</th>
<th>Mode</th>
<th>St. error</th>
<th>5%</th>
<th>Median</th>
<th>95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>Beta</td>
<td>0.75</td>
<td>0.1</td>
<td>0.899</td>
<td>0.002</td>
<td>0.887</td>
<td>0.893</td>
<td>0.899</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Normal</td>
<td>1.5</td>
<td>0.2</td>
<td>1.278</td>
<td>0.005</td>
<td>1.120</td>
<td>1.198</td>
<td>1.258</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Normal</td>
<td>0.5</td>
<td>0.2</td>
<td>0.322</td>
<td>0.011</td>
<td>0.236</td>
<td>0.306</td>
<td>0.373</td>
</tr>
<tr>
<td>$\mu_\pi$</td>
<td>Beta</td>
<td>0.5</td>
<td>0.2</td>
<td>0.910</td>
<td>0.006</td>
<td>0.901</td>
<td>0.911</td>
<td>0.922</td>
</tr>
<tr>
<td>$\delta_x$</td>
<td>Gamma</td>
<td>0.1</td>
<td>0.025</td>
<td>0.074</td>
<td>0.001</td>
<td>0.056</td>
<td>0.070</td>
<td>0.082</td>
</tr>
<tr>
<td>$\mu_x$</td>
<td>Beta</td>
<td>0.5</td>
<td>0.2</td>
<td>0.683</td>
<td>0.006</td>
<td>0.660</td>
<td>0.672</td>
<td>0.688</td>
</tr>
<tr>
<td>$\zeta_r$</td>
<td>Gamma</td>
<td>0.1</td>
<td>0.025</td>
<td>0.011</td>
<td>0.002</td>
<td>0.010</td>
<td>0.012</td>
<td>0.016</td>
</tr>
<tr>
<td>$\phi_\pi$</td>
<td>Beta</td>
<td>0.7</td>
<td>0.2</td>
<td>0.782</td>
<td>0.000</td>
<td>0.779</td>
<td>0.785</td>
<td>0.795</td>
</tr>
<tr>
<td>$\phi_x$</td>
<td>Beta</td>
<td>0.7</td>
<td>0.2</td>
<td>0.719</td>
<td>0.001</td>
<td>0.715</td>
<td>0.725</td>
<td>0.735</td>
</tr>
<tr>
<td>$\bar{r} \times 400$</td>
<td>Beta</td>
<td>5</td>
<td>1</td>
<td>5.365</td>
<td>0.094</td>
<td>5.074</td>
<td>5.324</td>
<td>5.588</td>
</tr>
<tr>
<td>$\sigma_p \times 10^2$</td>
<td>Inv gamma</td>
<td>0.02</td>
<td>4</td>
<td>0.023</td>
<td>0.000</td>
<td>0.017</td>
<td>0.019</td>
<td>0.025</td>
</tr>
<tr>
<td>$\sigma_q \times 10^2$</td>
<td>Inv gamma</td>
<td>0.2</td>
<td>4</td>
<td>0.285</td>
<td>0.001</td>
<td>0.283</td>
<td>0.292</td>
<td>0.299</td>
</tr>
<tr>
<td>$\sigma_\pi \times 10^2$</td>
<td>Inv gamma</td>
<td>0.1</td>
<td>4</td>
<td>0.039</td>
<td>0.000</td>
<td>0.036</td>
<td>0.038</td>
<td>0.040</td>
</tr>
<tr>
<td>$\sigma_x \times 10^2$</td>
<td>Inv gamma</td>
<td>0.05</td>
<td>4</td>
<td>0.022</td>
<td>0.000</td>
<td>0.021</td>
<td>0.022</td>
<td>0.023</td>
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</tbody>
</table>
\( \lambda_1 \times 10^{-2} : \text{posterior distribution}^2 \)

<table>
<thead>
<tr>
<th></th>
<th>( \pi_*^p )</th>
<th>( \pi_*^q )</th>
<th>( \pi )</th>
<th>( x )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \pi_*^p )</td>
<td>0.080</td>
<td>1.589</td>
<td>-3.080</td>
<td>6.775</td>
</tr>
<tr>
<td></td>
<td>(-0.167, 0.489)</td>
<td>(1.250, 1.797)</td>
<td>(-3.333, -2.908)</td>
<td>(6.663, 6.901)</td>
</tr>
<tr>
<td>( \pi_*^q )</td>
<td>-0.421</td>
<td>-0.327</td>
<td>0.688</td>
<td>8.211</td>
</tr>
<tr>
<td></td>
<td>(-0.698, -0.272)</td>
<td>(-0.363, -0.287)</td>
<td>(0.613, 0.809)</td>
<td>(7.933, 8.424)</td>
</tr>
<tr>
<td>( \pi )</td>
<td>0.040</td>
<td>2.284</td>
<td>-7.389</td>
<td>5.552</td>
</tr>
<tr>
<td></td>
<td>(-0.252, 0.406)</td>
<td>(2.132, 2.629)</td>
<td>(-7.660, -7.101)</td>
<td>(4.813, 6.623)</td>
</tr>
<tr>
<td>( x )</td>
<td>0.638</td>
<td>1.998</td>
<td>-3.713</td>
<td>-2.560</td>
</tr>
<tr>
<td></td>
<td>(0.545, 0.746)</td>
<td>(1.845, 2.219)</td>
<td>(-3.845, -3.490)</td>
<td>(-3.108, -2.213)</td>
</tr>
</tbody>
</table>

Median values; 5\% and 95\% percentiles in parentheses

1. For the Inverted gamma distribution, the degrees of freedom are indicated. 2. For all lambda parameters, the prior distribution is Normal with mean zero and standard error 100.