The Term Structure Of Inflation Expectations

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Monetary policy effectiveness

- Monetary policy (MP) matters for the real economy
  - How effective is MP in the US?

"...the economic system will work best when producers and consumers, employers and employees, can proceed with full confidence that the average level of prices will behave in a known way in the future -- preferably that it will be highly stable." -- Friedman (1968)
Monetary policy effectiveness

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Optimal monetary policy

- In the rational expectations equilibrium (REE), the optimal MP entails a response to shocks in inflation and output.
- If private sector expectations deviate from rational expectations, then REE optimal MP will lead to instability.
- Optimal MP should respond to private sector expectations or their determinants.
Questions

- Is there any evidence that US MP responds to private sector expectations?

- If yes, does it lead to anchored expectations?
Are private sector expectations observed?

- Nominal yields are noisy measures of expectations
- Survey forecasts are supposed to be direct measures
The Term Structure of Inflation Forecasts
Are private sector expectations observed?

- Nominal yields are noisy measures of expectations
- Survey forecasts are supposed to be direct measures
- Is information in yields consistent with that of the surveys?
Approach

- We build a joint model of survey forecasts and UST yields
- Measure private sector inflation expectations
- Establish the determinants of these expectations
- Does the policy respond to these determinants?
- Are expectations anchored?
- Implication: Out-of-sample inflation forecasting
Summary of findings

- Private sector expectations measurement requires information from both yields and surveys.
- The expectations are driven by inflation, output, and an independent “survey” factor that is needed to model all the inflation expectations at all maturities.
- The interest rate rule loads on the “survey” factor, that is, MP responds to variables outside of the standard set.
- Monetary policy appears to be more effective recently.
- Inflation expectations outperform those of a “standard” macro-finance model.
Modeling strategy

- It is natural to investigate these issues in a model that incorporates macro variables, forecasts and yields.
- Macro-finance term structure model with a twist.
- We accommodate macro variables (\(\mathbb{P}\)-measure), yields (\(\mathbb{Q}\)-measure), and surveys (\(\mathbb{P}^i\)-measure):
  - Allows for multiple surveys.
  - State-dependent biases.
  - Can establish the “marginal” expectations.
States of the economy

- Objective probability measure

- Factors – Gaussian VAR(1):

\[ z_t = \mu + \Phi z_{t-1} + \sum \epsilon_t, \quad z_t = \begin{pmatrix} g_t, \pi_t, x_{1t}, x_{2t} \end{pmatrix} \]

- Inflation forecast:

\[ E_t^P(\pi_{t+\tau}) = e_2' (I - \Phi)^{-1} (I - \Phi^T) \mu + \Phi^T z_t \]
Yields

- Spot interest rate:
  \[ r_t = \delta_0 + \delta' z_t \]

- Stochastic discount factor:
  \[ \log \xi_t = -r_{t-1} - \frac{1}{2} \Lambda'_{t-1} \Lambda_{t-1} - \Lambda_{t-1} \epsilon_t \]

- Risk-neutral probability measure
  \[ \mathbb{Q} \]

- Essentially-affine risk premia:
  \[ \Lambda_t = \Lambda_0 + \Lambda_z z_t \]

- Bond yields:
  \[
y_t(\tau) = -\frac{1}{\tau} \log E_t \left( \prod_{s=t+1}^{t+\tau} \xi_s \right) \triangleq a^P(\tau) + b^P(\tau)' z_t + a^{TP}(\tau) + b^{TP}(\tau)' z_t \]
  \text{Short rate expectations} \quad \text{Term premium}
Incorporating survey forecasts

- How do we include the forecast data given this framework?

- Look quite different from each other and realized inflation
  - Biases?
  - Errors?
Different signals

- Forecaster $i$ believes that only her signal is correlated with state variables.
- The forecast is computed under *subjective* measure $\mathbb{P}^i$.
  - Related to the heterogeneous agents framework (Harrison and Kreps, 1978; Scheinkman and Xiong, 2003; Dumas, Kurshev and Uppal, 2007; ...).
Asymmetric loss functions

- Forecasters have asymmetric (and different) loss functions
  - Linex \( e^{a_i \cdot \text{error}} - a_i \cdot \text{error} - 1 \)
  - The optimal forecast is biased
  - Forecast errors are autocorrelated

- Under regularity, there exist a measure \( \mathbb{P}^i \) under which
  - The optimal forecast is unbiased
  - Forecast errors are iid

(Patton and Timmerman, 2007)
Subjective Forecasters

- Survey forecasters may have different private signals, loss functions:

\[ E_t^{\mathbb{P}^i} (\pi_{t+\tau}) \neq E_t^{\mathbb{P}^j} (\pi_{t+\tau}) \neq E_t^{\mathbb{P}} (\pi_{t+\tau}) \]

- Survey-specific probability measure:

\[ \mathbb{P}^i : \log \xi_t^i = -\frac{1}{2} \Lambda_t^{i'} \Lambda_t^i - \Lambda_{t-1}^i \epsilon_t, \]

\[ E_t^{\mathbb{P}^i} (\pi_{t+\tau}) = \epsilon_2' \left( (I - \Phi_i)^{-1} (I - \Phi_i^T) \mu_i + \Phi_i^T z_t \right) \]

- Reported forecasts:

\[ \bar{p}_{t,0}^i (\tau) \triangleq E_t^{\mathbb{P}^i} (\pi_{t+\tau}) \triangleq \alpha^\mathbb{P} (0, \tau) + b^\mathbb{P} (0, \tau)' z_t + a^{TB_i} (0, \tau)' z_t + b^{TB_i} (0, \tau)' z_t. \]

Term bias
What should we expect to see?

- Measure private sector inflation expectations
  - How do they behave over time?
  - Do subjective and objective expectations coincide?

- Establish the determinants of these expectations
  - How do expectations load on the model factors?
  - Are the factor related to interesting objects?

- Does monetary policy respond to these determinants?

- Evaluate effectiveness of the monetary policy
  - Inflation premia
  - Changes in inflation’s persistence
  - How do medium- and long-term expectations behave out-of-sample?

- Out-of-sample inflation forecasting
Data and Methodology

- 1970-2004, quarterly frequency (140 quarters)
- Macro variables: GDP and CPI
- Inflation forecasts: Michigan, Livingston, SPF, Blue Chip
- Unsmoothed Fama-Bliss zero yields with 8 maturities ranging from 3 months to 10 years
- Estimation:
  - ML with Kalman filter
  - Allow for missing observations (for forecasts)

\[
y_t(\tau) = a^Q(\tau) + b^Q(\tau)' z_t + \xi_t \quad (8 \text{ yields})
\]

\[
\overline{p}^i_{t,s}(\tau) = a^i(s, \tau) + b^i(s, \tau)' z_t + \chi^i_{t,s}(\tau) \quad (20 \text{ forecasts})
\]

\[
z_t = \mu + \Phi z_{t-1} + \Sigma \epsilon_t \quad \text{(State equation)}
\]
Term Bias: $E_t^{IPi} (\pi_{t+\tau}) - E_t^{IP} (\pi_{t+\tau})$
Additional Models

\[ y_t(\tau) = a^Q(\tau) + b^Q(\tau)'z_t + \xi_t \quad (8 \text{ yields}) \]

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\[ z_t = \mu + \Phi z_{t-1} + \Sigma \epsilon_t \quad \text{(State equation)} \]
$$E_t^{\text{IP}}(\pi_{t+\tau}) = e_2' \left( (I - \Phi)^{-1} (I - \Phi^\top) \mu + \Phi^\top z_t \right)$$

Factor loadings

GDP

Inflation

Latent 1

Latent 2
Determinants of Forecasts: Simple Filters

\[ x_{it} = A_{i0} + A_{im}m_t + A_{iy}y_t + A_{ip}\bar{p}_t + A_{il}x_{it-1} \]
Determinants of Forecasts: Simple Filters

\[ x_{it} = A_{i0} + A_{im} m_t + A_{iy} y_t + A_{ip} \bar{p}_t + A_{il} x_{it-1} \]

<table>
<thead>
<tr>
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<th>Factor</th>
<th>( m_t )</th>
<th>( y_t(\tau) )</th>
<th>( \bar{p}_t(s,t) )</th>
<th>corr</th>
</tr>
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<tbody>
<tr>
<td>AO</td>
<td>( x_1 )</td>
<td>( g, \pi )</td>
<td>( _ )</td>
<td>LS(0,4), SPF(0,4)</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>( x_2 )</td>
<td>( _ )</td>
<td>1, 40</td>
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- \( f_1 \) continues to have strong correlation with forecasts
  - where \( f_t \) is orthogonal to \( M_t \) (\( m_t \) and its history)

\[ x_t = \hat{x}(M_t) + f_t \]
Does the interest rate respond to $f_1$?

<table>
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<th>Horizon</th>
<th>$M$</th>
<th>$f_1$</th>
<th>$f_2$</th>
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<tbody>
<tr>
<td>1</td>
<td>50.07</td>
<td>19.22</td>
<td>30.71</td>
</tr>
<tr>
<td>8</td>
<td>41.16</td>
<td>20.90</td>
<td>37.93</td>
</tr>
<tr>
<td>40</td>
<td>38.59</td>
<td>22.63</td>
<td>38.77</td>
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\[ y_t(\tau) = y_t^R(\tau) + \bar{p}_{t,0}(\tau) + IP_t(\tau) \]  

The Fisher equation
Changing impulse responses
Changing conditional expectations

Out-of-sample forecasts: 5 years

Out-of-sample forecasts: 10 years

Legend:
- Realized Inflation
- AO Model
- NF Model
- TIPS adj
Out-of-sample inflation forecasting

- AO outperforms NF by 25% to 60% (RMSE ratios)
- AO is very similar to the survey forecasts
- But, AO is available for any horizon of interest at any point in time
Conclusions

- We construct a no-arbitrage model that incorporates macro variables, yields and inflation forecasts in a internally consistent manner
- Both yields and surveys are required to construct inflation expectations
- Inflation expectations are driven by the history of macro variables and “survey” factor
- The implied term structure of inflation expectations is:
  - Reasonable
  - Instrumental in identifying real yields and inflation premia
  - Suggests that monetary policy became more effective over time
  - Forecasts inflation and yields well