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?

Monetary policy effectiveness

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  - 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)

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

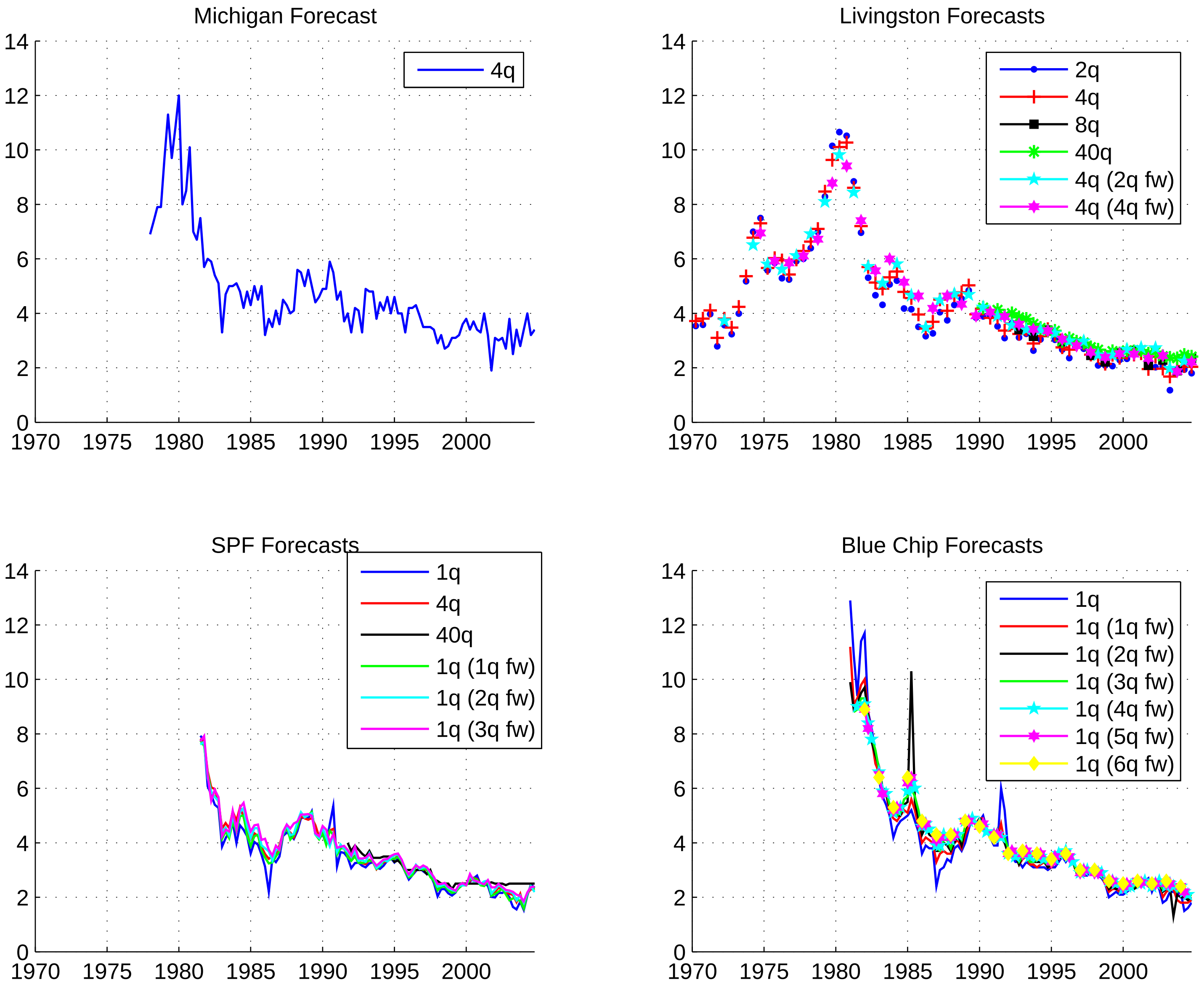
- Is there any evidence that US MP responds to private sector expectations?
- If yes, does it lead to anchored expectations?

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

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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 $\mathbb{P}$
- Factors – Gaussian VAR(1): $z_t = \mu + \Phi z_{t-1} + \Sigma \epsilon_t, \;\; z_t = (\underbrace{g_t, \pi_t}_{m_t}, x_{1t}, x_{2t})$
- Inflation forecast: $E_t^{\mathbb{P}}(\pi_{t+\tau}) = e_2' \left((I - \Phi)^{-1} (I - \Phi^{\tau}) \mu + \Phi^{\tau} z_t \right)$

Yields

- Spot interest rate: $r_t = \delta_0 + \delta_z' z_t$
- 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:

$$y_t(\tau) = -\frac{1}{\tau}\log E_t\left(\prod_{s=t+1}^{t+\tau}\xi_s\right) \triangleq \underbrace{a^{\mathbb{P}}(\tau) + b^{\mathbb{P}}(\tau)'z_t}_{\text{Short rate expectations}} + \underbrace{a^{TP}(\tau) + b^{TP}(\tau)'z_t}_{\text{Term premium}}$$

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; …)

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Asymmetric loss functions

- Forecasters have asymmetric (and different) loss functions
  - Linex $e^{a_i \cdot \mathrm{error}} - a_i \cdot \mathrm{error} - 1$
  - 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)

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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:

$$\begin{aligned} \mathbb{P}^i : \log \xi_t^i &= -\frac{1}{2}\Lambda_{t-1}^{i\prime}\Lambda_{t-1}^i - \Lambda_{t-1}^i \epsilon_t, \\ E_t^{\mathbb{P}^i}(\pi_{t+\tau}) &= e_2'\left((I-\Phi_i)^{-1}(I-\Phi_i^\tau)\mu_i + \Phi_i^\tau z_t\right) \end{aligned}$$

- Reported forecasts:

$$\overline{p}_{t,0}^i(\tau) \triangleq E_t^{\mathbb{P}^i}(\pi_{t+\tau}) \triangleq \underset{E_t^{\mathbb{P}}(\pi_{t+\tau})}{a^{\mathbb{P}}(0,\tau) + b^{\mathbb{P}}(0,\tau)' z_t} + \underset{\text{Term bias}}{a^{TBi}(0,\tau) + b^{TBi}(0,\tau)' z_t} \; .$$

What should we expect to see?

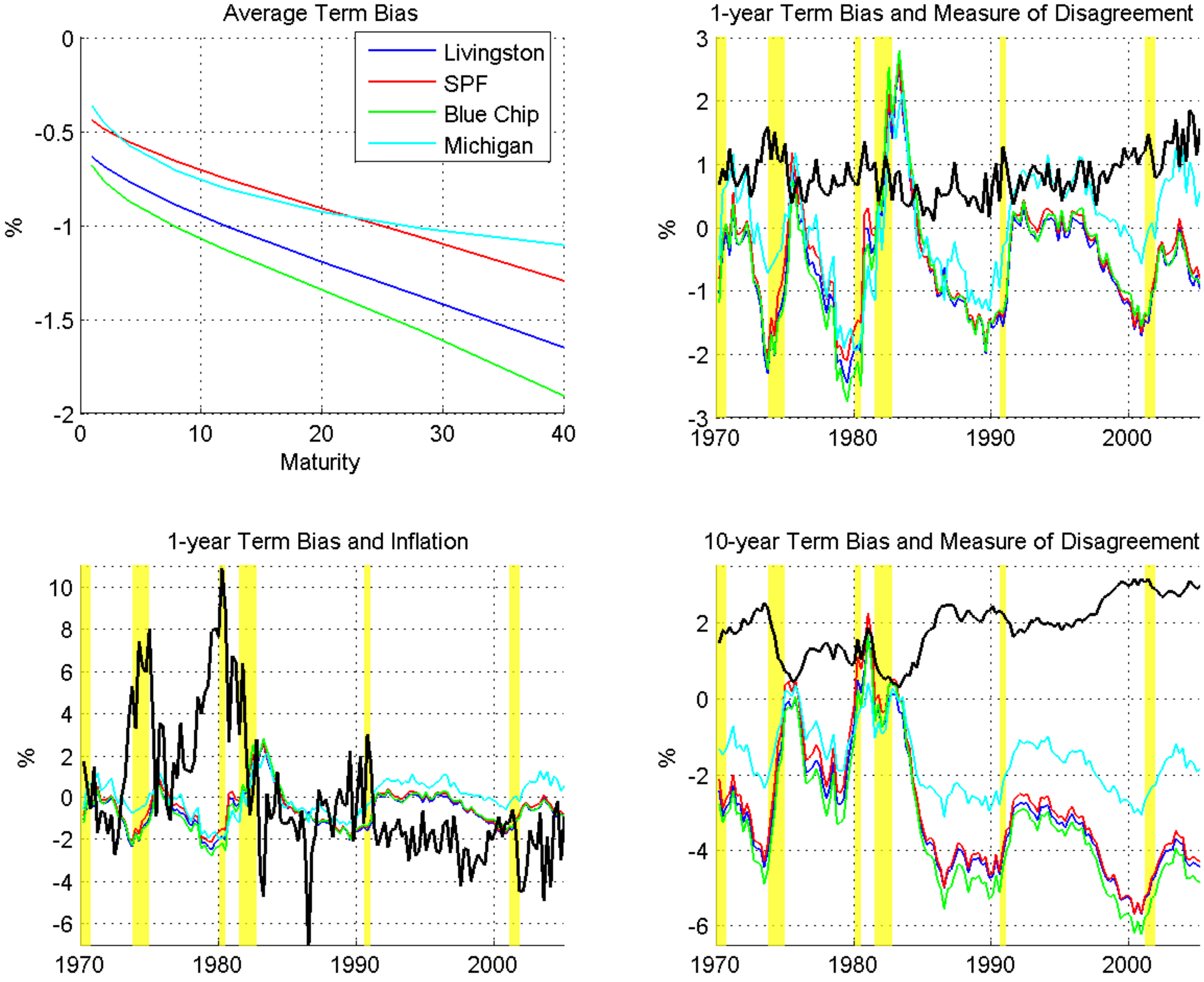
- Measure private sector inflation expectations
  - How do they behave over time?
  - Do subjective and objective expectations coincide?
- Establish the determinants of these expectations
  - How do expectations load on the model factors?
  - Are the factor related to interesting objects?
- Does monetary 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)

$$
\begin{aligned}
y_t(\tau) &= a^{\mathbb{Q}}(\tau) + b^{\mathbb{Q}}(\tau)' z_t + \xi_t \ \text{(8 yields)} \\
\overline{p}^i_{t,s}(\tau) &= a^i(s,\tau) + b^i(s,\tau)' z_t + \chi^i_{t,s}(\tau) \ \text{(20 forecasts)} \\
z_t &= \mu + \Phi z_{t-1} + \Sigma \epsilon_t \ \text{(State equation)}
\end{aligned}
$$

Term Bias: $E_t^{\mathbb{P}^i}(\pi_{t+\tau}) - E_t^{\mathbb{P}}(\pi_{t+\tau})$



Additional Models

AO

$\mathbb{P}^i = \mathbb{P}$

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OF

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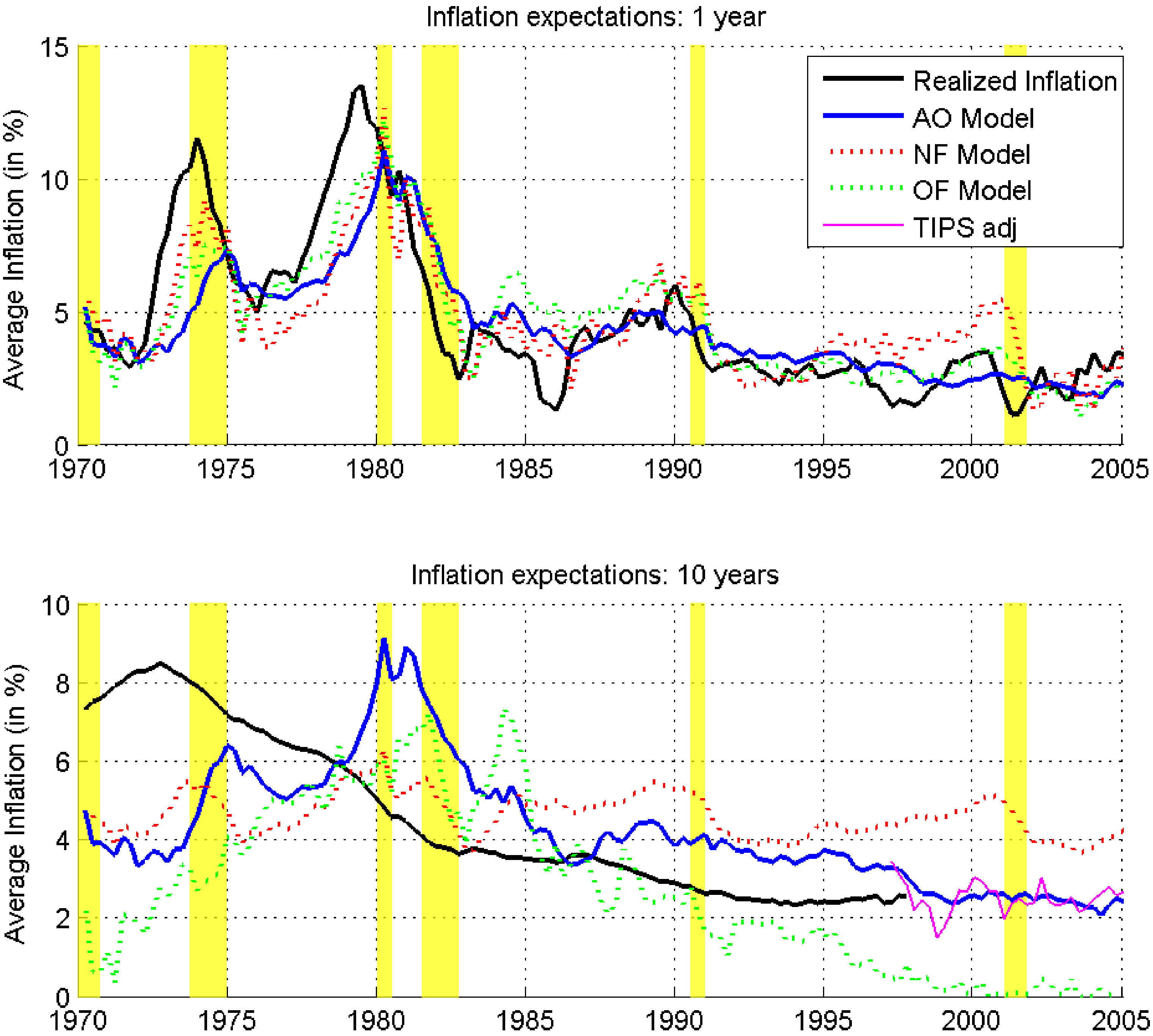
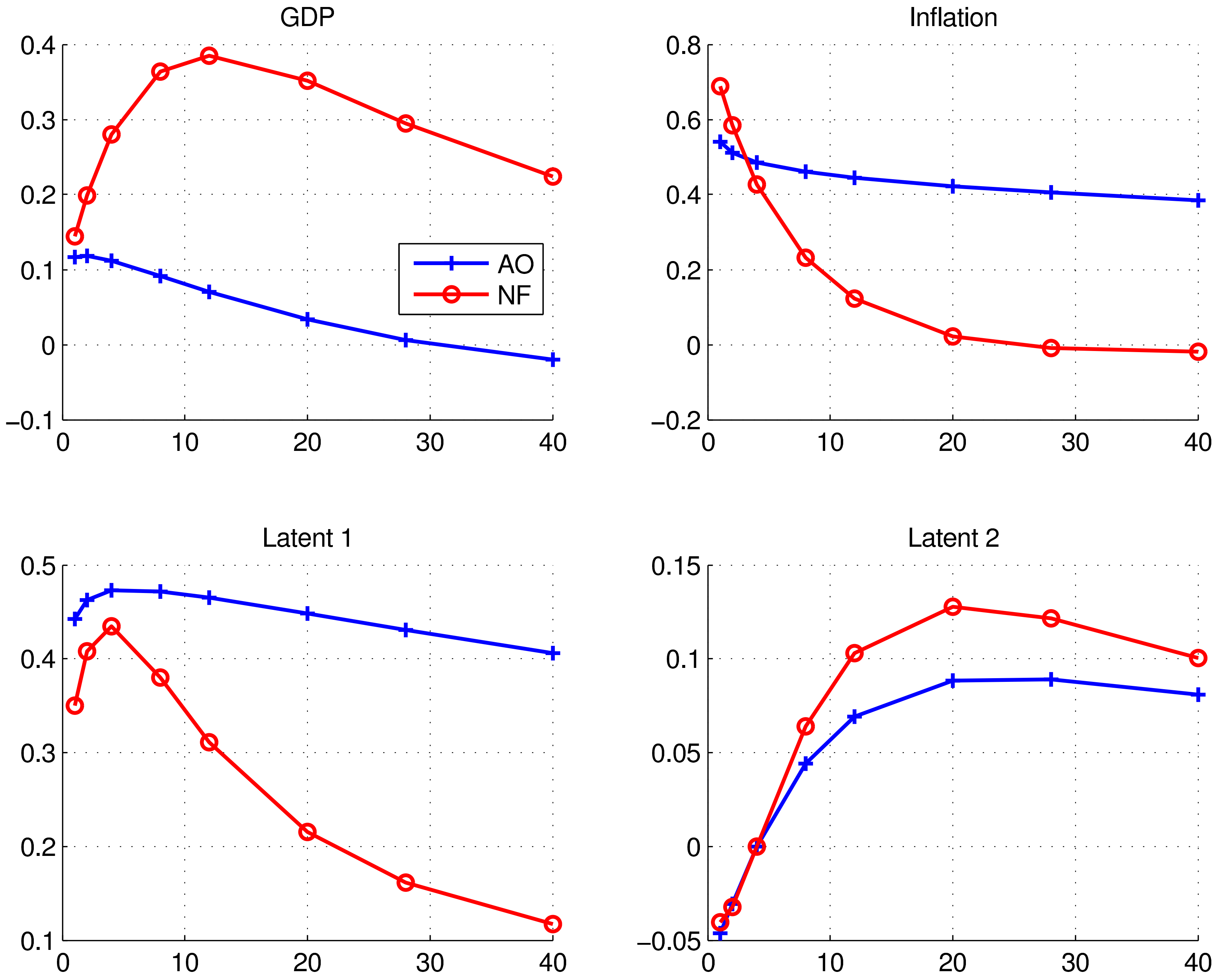

Inflation expectations: 1 year
Average Inflation (in %)
15
10
5
0
1970
1975
1980
1985
1990
1995
2000
2005
Realized Inflation
AO Model
NF Model
OF Model
TIPS adj
Inflation expectations: 10 years
Average Inflation (in %)
10
8
6
4
2
0
1970
1975
1980
1985
1990
1995
2000
2005

$$E_t^{\mathbb{P}}(\pi_{t+\tau}) = e_2'\left((I-\Phi)^{-1}(I-\Phi^{\tau})\mu + \Phi^{\tau} z_t\right)$$

Factor loadings



Determinants of Forecasts: Simple Filters

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

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Model	Factor	m_t	$y_t(\tau)$	$\overline{p_t}(s,t)$	corr
AO	x_1	g, π	–	LS(0,4), SPF(0,4)	0.99
	x_2	–	1, 40	LS(0,4), SPF(0,4)	0.98

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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)

$$x_t = \widehat{x}(M_t) + f_t$$

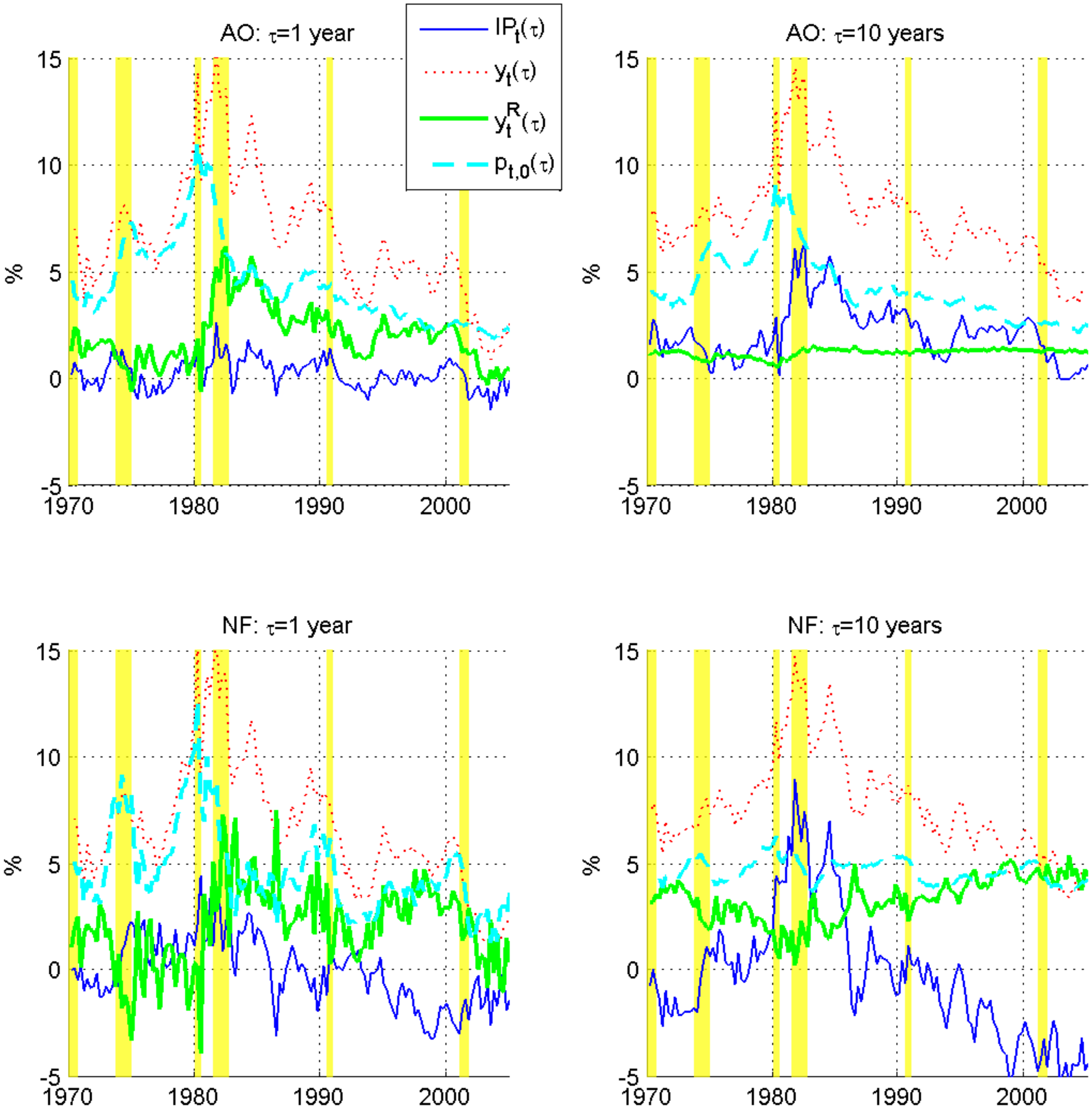
Does the interest rate respond to f_1?

Theoretical R^2 for yields

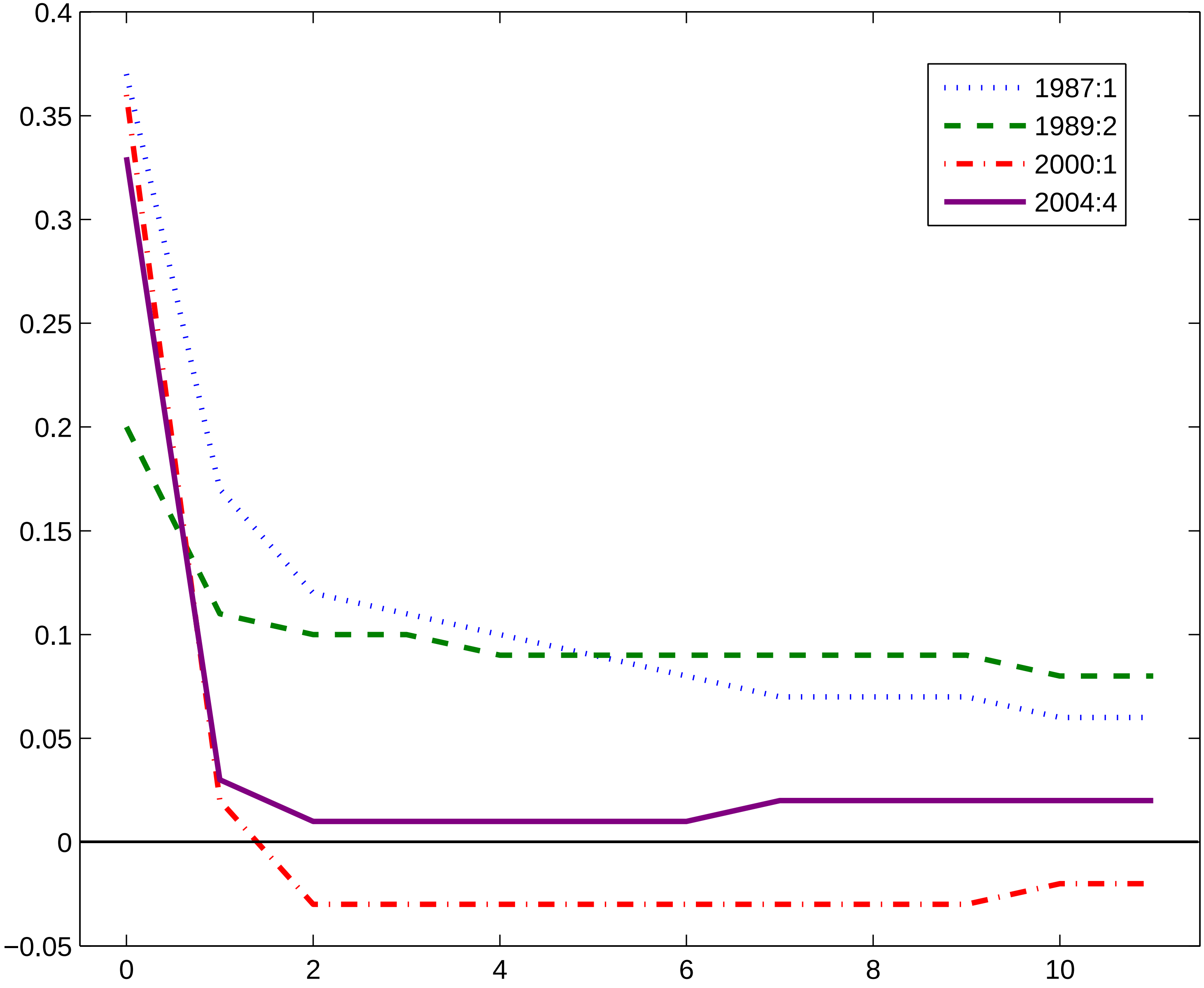
Horizon	M	f_1	f_2
1	50.07	$\boxed{19.22}$	30.71
8	41.16	20.90	37.93
40	38.59	22.63	38.77

$$y_t(\tau) = y_t^R(\tau) + \overline{p}_{t,0}(\tau) + IP_t(\tau)$$

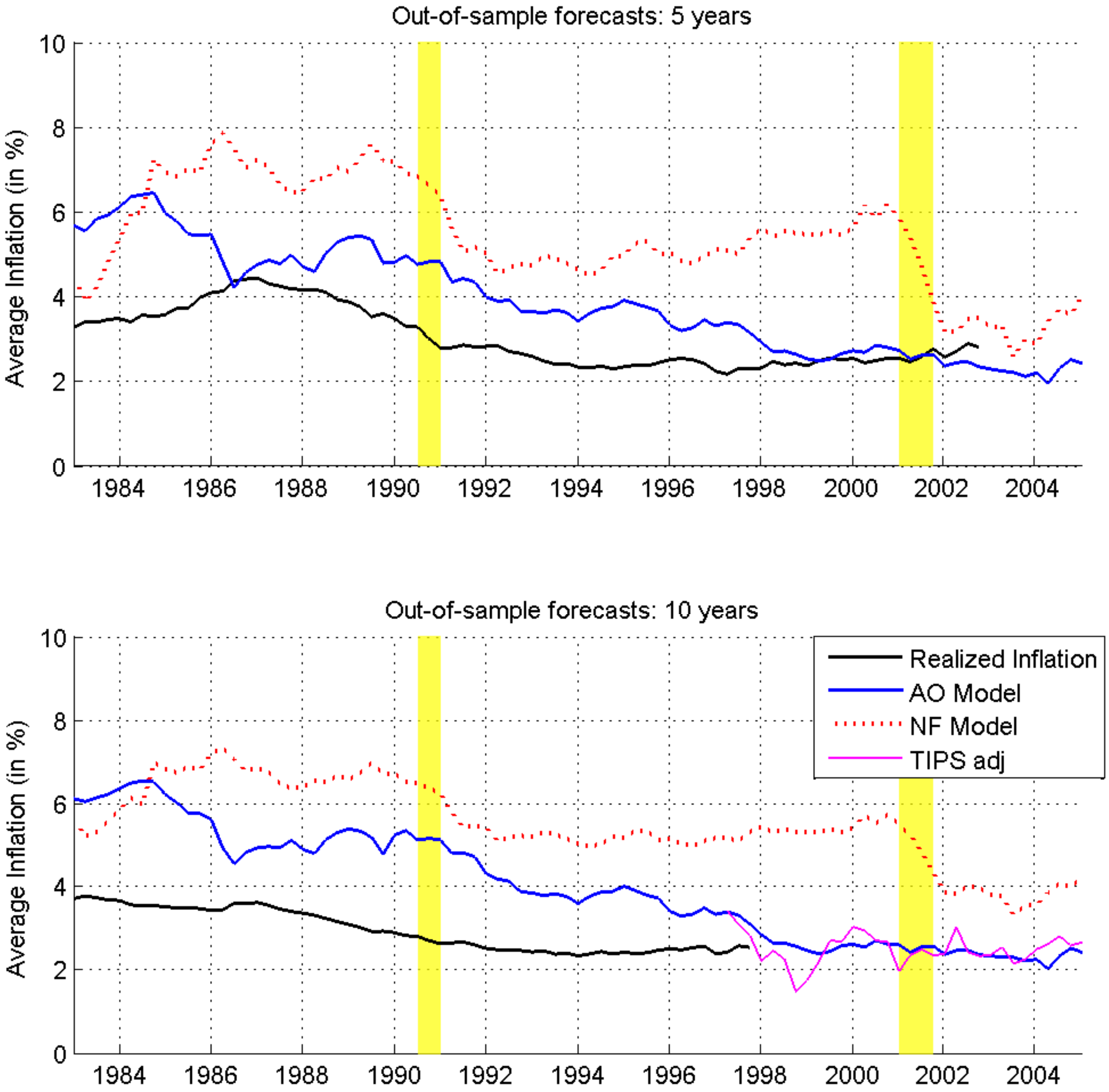
The Fisher equation



Changing impulse responses

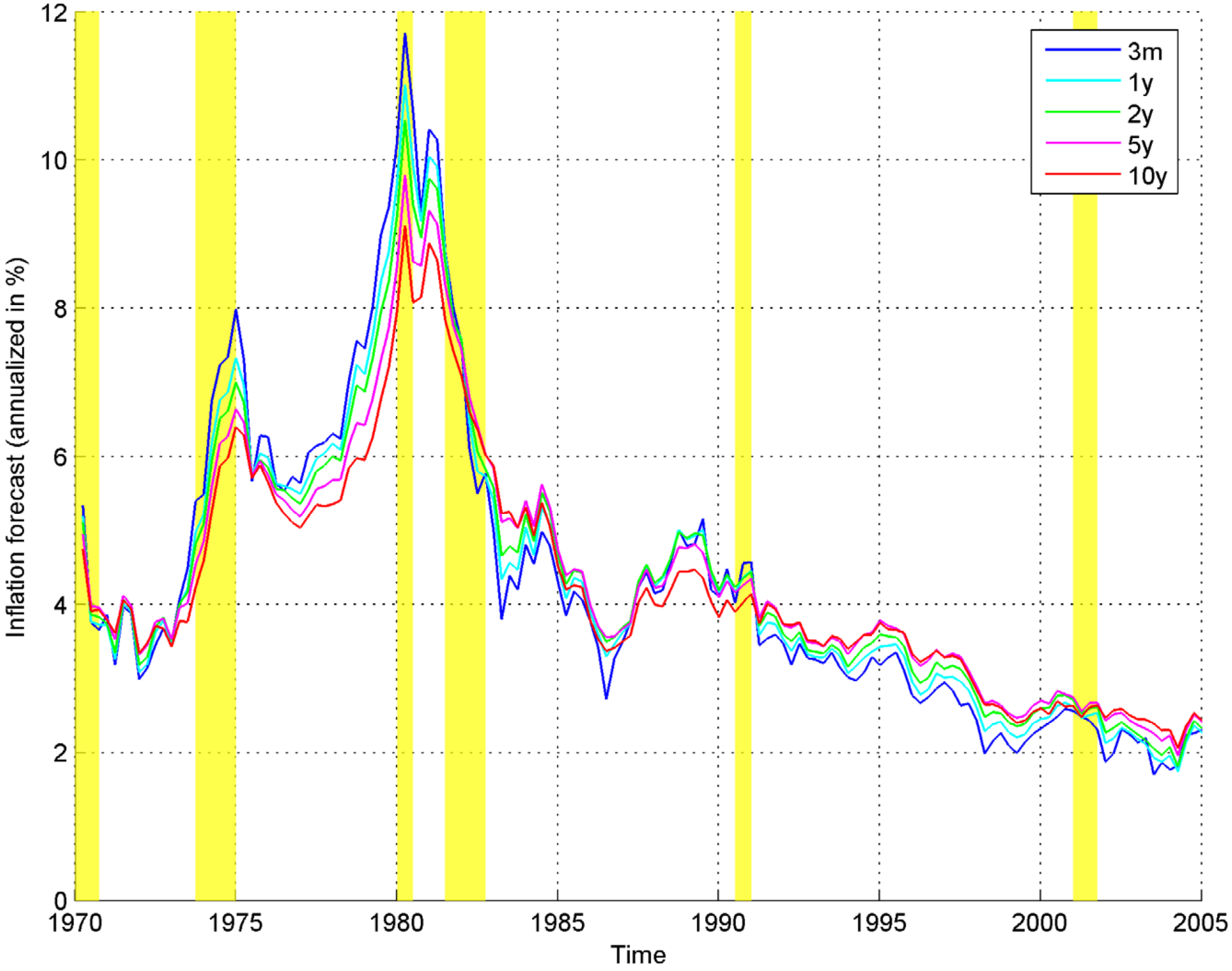


Changing conditional expectations



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



3m
1y
2y
5y
10y
Inflation forecast (annualized in %)
0
2
4
6
8
10
12
1970
1975
1980
1985
1990
1995
2000
2005
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