Trend and Cycle in Bond Premia

Monika Piazzesi — Stanford & NBER

Martin Schneider — Stanford & NBER

Minneapolis , October 10 2008

Motivation

- stylized fact: excess returns on long bonds are predictable

Motivation

- stylized fact: excess returns on long bonds are predictable

- definitions

  - log excess return on zero coupon bond of maturity n years, held for 1 year

    $$= \text{log price next year} \quad - \text{log price today} \quad - \text{1 year interest rate}$$

    $$= \quad p_{t+1}^{(n-1)} \quad - \quad p_t^{(n)} \quad - \quad i_t^{(1)} \quad := rx_{t+1}^{(n)}$$

  - predictability: premium $\hat{E}_t rx_{t+1}^{(n)}$ moves around

    $\hat{E}_t$ computed from statistical model –> "*statistical* premium"

    e.g., fitted value from regressing $rx_{t+1}^{(n)}$ on time-t variables

Motivation

- stylized fact: excess returns on long bonds are predictable

$=$ statistical premium $\hat{E}_t rx_{t+1}^{(n)}$ moves around; e.g.

  - higher after recessions, lower at end of booms
  - higher in 1980s, lower in 1970s

$\Longrightarrow$ puzzle: why did investors not exploit predictability? Two candidate answers:

1. historical expectations $\neq \hat{E}_t rx_{t+1}^{(n)}$
2. historical expectations $= \hat{E}_t rx_{t+1}^{(n)} =$ (compensation for risk)$_t$

- most models: only 2.

- This paper: model of both; evidence of 1. from surveys

This paper

- investors learn about dynamics of interest rates, inflation, real activity

- learning process determines

  1. subjective forecasts $E_t rx_{t+1}^{(n)}$ – compare to survey data

  2. subjective risk

- Euler equation: $E_t rx_{t+1}^{(n)} =$ (compensation for *subjective* risk)$_t$

- decompose statistical premium

$$\hat{E}_t rx_{t+1}^{(n)} = \underbrace{\left(\hat{E}_t rx_{t+1}^{(n)} - E_t rx_{t+1}^{(n)}\right)}_{\text{forecast difference}} + (\text{compensation for subjective risk})_t$$

Message

- decompose statistical premium

$$\hat{E}_t rx_{t+1}^{(n)} = \underbrace{\left(\hat{E}_t rx_{t+1}^{(n)} - E_t rx_{t+1}^{(n)}\right)}_{\text{forecast difference}} + (\text{compensation for subjective risk})_t$$

- Movements in forecast difference
  - forecasts lag behind trends, do not react much to sudden changes

$\Longrightarrow$ forecast differences low in 70s, high in 80s, countercyclical.

- Movements in compensation for subjective risk
  - with recursive utility, relevant risk is Cov (bond returns, news about growth)
  - risk increases over 1970s, drops later

$\Longrightarrow$ subjective premium slow-moving, high in 80s

Outline

1. Stylized facts about survey forecasts

   (a) pictures for one bond, one forecast horizon

   (b) compress info from forecasts for many maturities, horizons
   (using factor model)

$\Longrightarrow$ forecasts made as if level & slope of yield curve more persistent

$\Longrightarrow$ subjective premium much less volatile, cyclical, especially for long maturities

2. consumption based asset pricing model with learning:

   learning explains forecast differences and subjective risk premia

Related Literature

- predictability regressions

  Fama & Bliss 1987, Campbell & Shiller 1991, etc

- statistical analysis of interest rate survey data

  Froot 1989, Kim & Orphanides 2007, Chernov & Mueller 2008

- role of survey expectations in other markets

  Frankel & Froot 1989, Gourinchas & Tornell 2004, Bacchetta et al. 2008

- asset pricing with recursive utility

  Epstein & Zin 1989, Bansal & Yaron 2004, Hansen, Heaton, Li 2008

Properties of Survey Forecasts

- 2 datasets: Goldsmith-Nagan surveys 1970-1986 & Bluechip surveys 1983 - today

- each quarter, 40 market participants are asked about their interest-rate expectations

- look at median, max horizons: 2 quarters for GN, 1 year for Bluechip

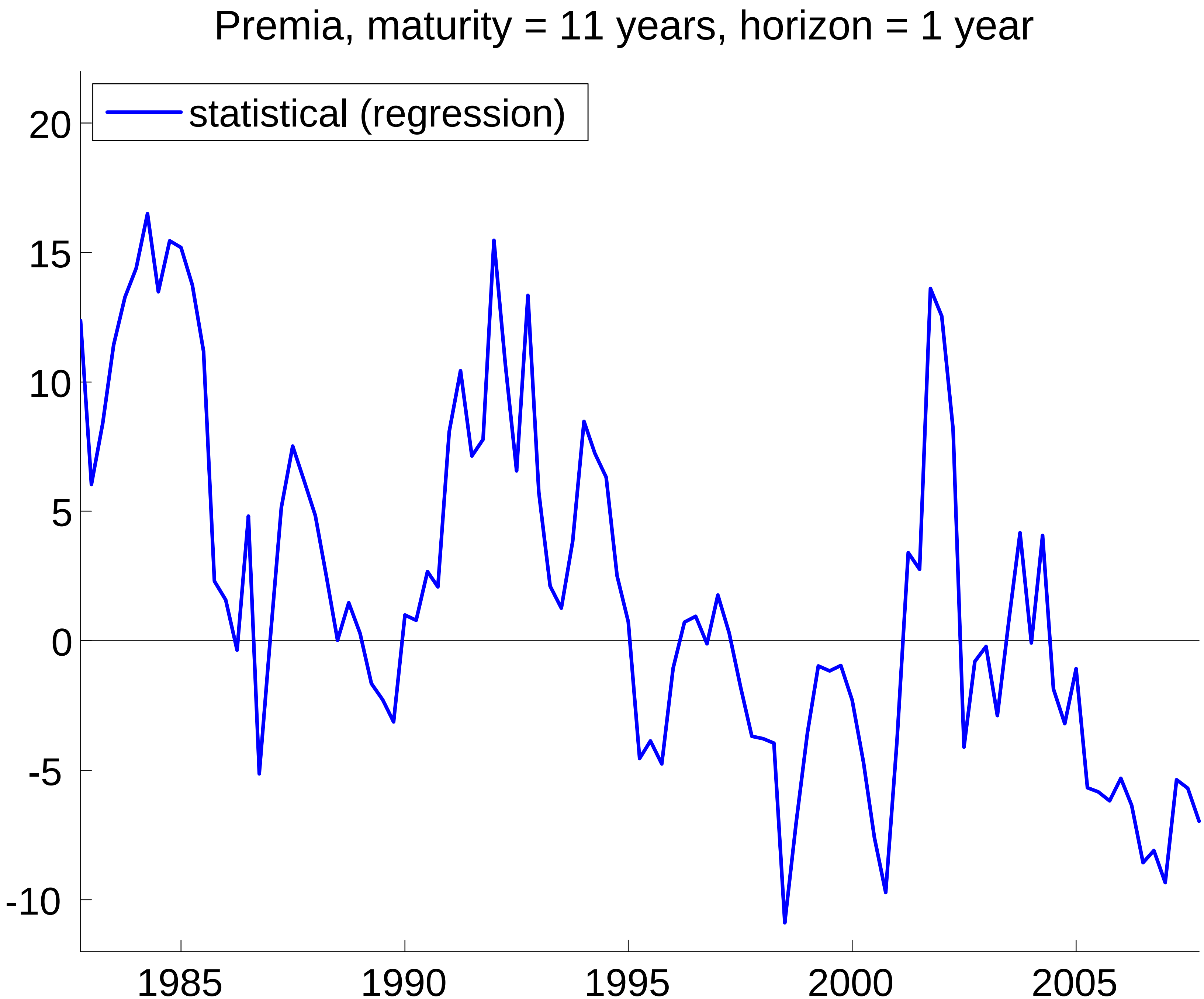
- decomposition for bond of maturity n years, held for horizon h years

$$\hat{E}_t rx_{t+h}^{(n)} = \left(\hat{E}_t rx_{t+h}^{(n)} - E_t rx_{t+h}^{(n)} \right) + (\text{compensation for risk})_t$$

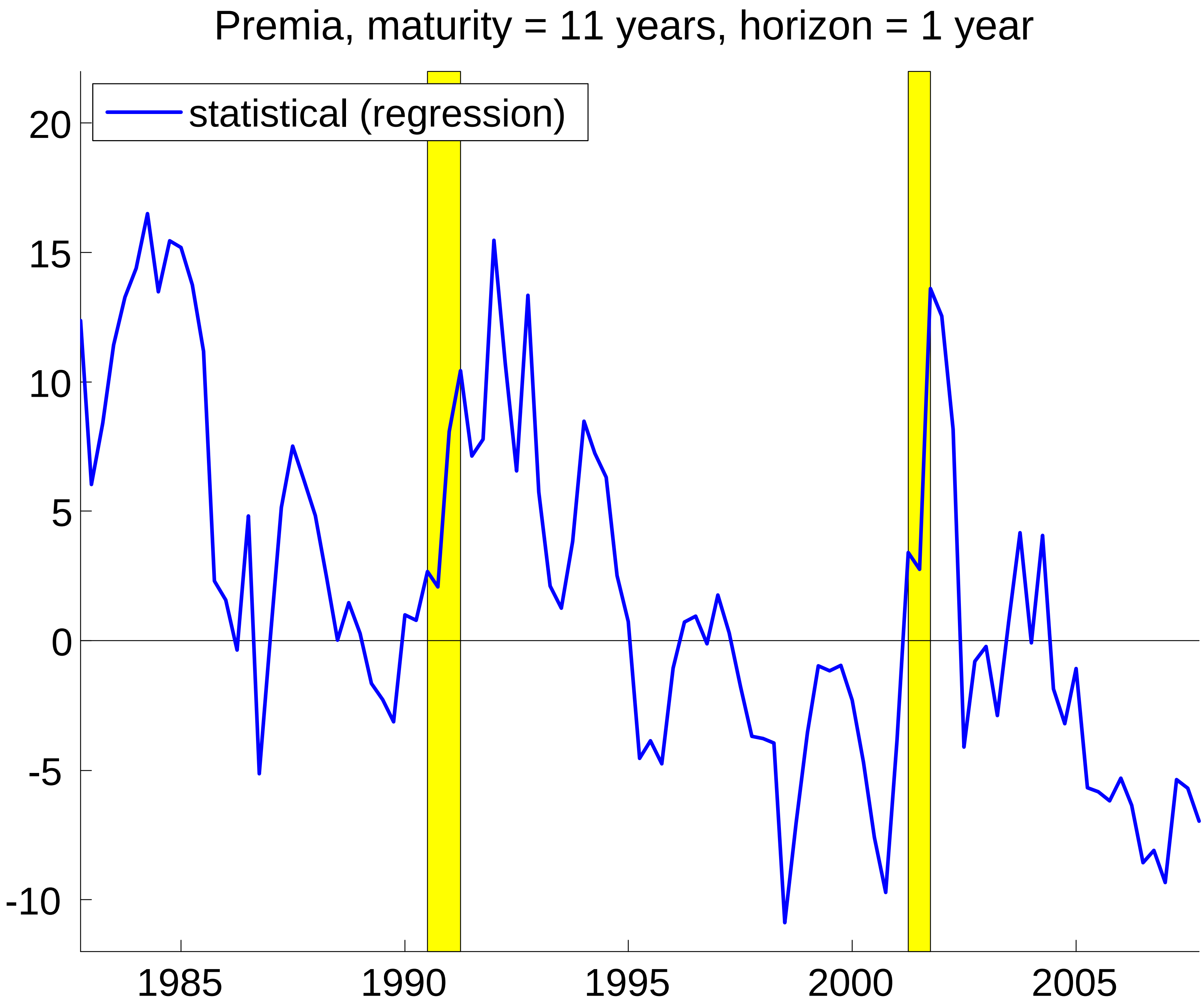
  - measure $\hat{E}_t rx_{t+h}^{(n)}$ with regressions

  - measure $E_t rx_{t+h}^{(n)} = E_t p_{t+h}^{(n-h)} - p_t^{(n)} - i_t^{(h)}$
    with interest-rate surveys $E_t p_{t+1}^{(n-1)} = -(n-1)\, E_t i_{t+1}^{(n-1)}$

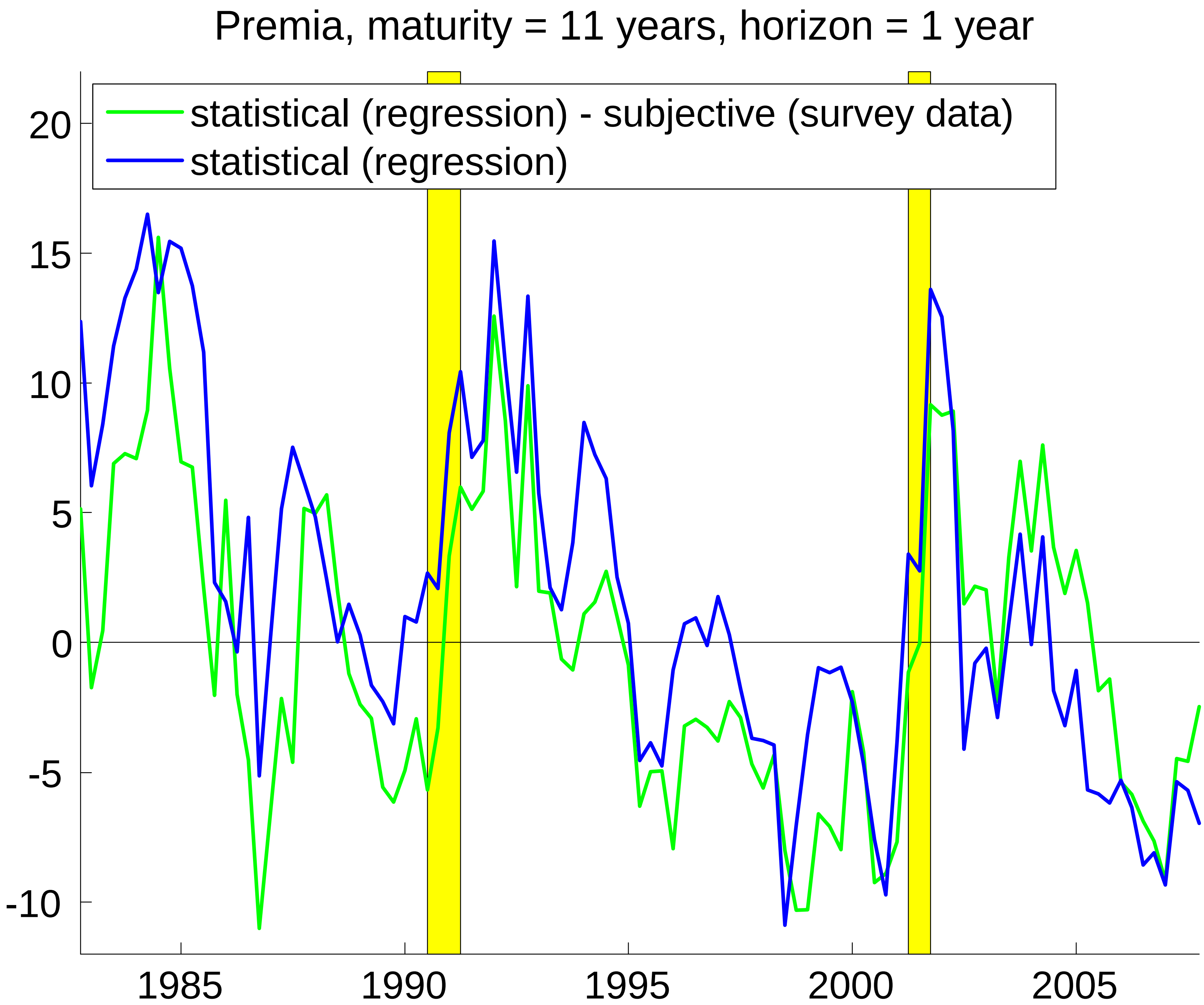
example: $n = 11$ years, $h = 1$ year for Bluechip



Premia, maturity = 11 years, horizon = 1 year
statistical (regression)
20
15
10
5
0
-5
-10
1985
1990
1995
2000
2005



Premia, maturity = 11 years, horizon = 1 year
statistical (regression)
20
15
10
5
0
-5
-10
1985
1990
1995
2000
2005


Premia, maturity = 11 years, horizon = 1 year
statistical (regression) - subjective (survey data)
statistical (regression)
20
15
10
5
0
-5
-10
1985
1990
1995
2000
2005

Outline

1. Stylized facts about survey forecasts

   (a) pictures for one bond, one forecast horizon

   (b) compress info from forecasts for many maturities, horizons
   (using factor model)

$\Longrightarrow$ forecasts made as if level & slope of yield curve more persistent

$\Longrightarrow$ subjective premium much less volatile & cyclical, especially for long maturities

2. consumption based asset pricing model with learning:

   learning explains forecast differences and subjective risk premia

Compressing info

- goal: combine info in forecasts for all dates, bond maturities, forecast horizons

- quarterly state space system:
  observables are interest rates, inflation, consumption growth

$$\begin{aligned} \text{observables}_t &= \mu_z + \phi_z \ \text{factors}_{t-1} + \sigma_z e_t \\ \text{factors}_t &= \phi_f \ \text{factors}_{t-1} + \sigma_f e_t \end{aligned}$$

- statistical forecasts

$$\hat{E}_t \left[\text{observables}_{t+h}\right] = \mu_z + \phi_z \left(\phi_f\right)^h \ \text{factors}_t$$

- assume same functional form for survey forecasts

$$E_t \left[\text{observables}_{t+h}\right] = \mu_z + \phi_z^* \left(\phi_f^*\right)^h \ \text{factors}_t$$

- estimate ϕ_z^*, ϕ_f^* from survey forecast data

$\Longrightarrow$ survey forecasts look like from system with more persistent level, slope

Comparison of subjective & statistical premia

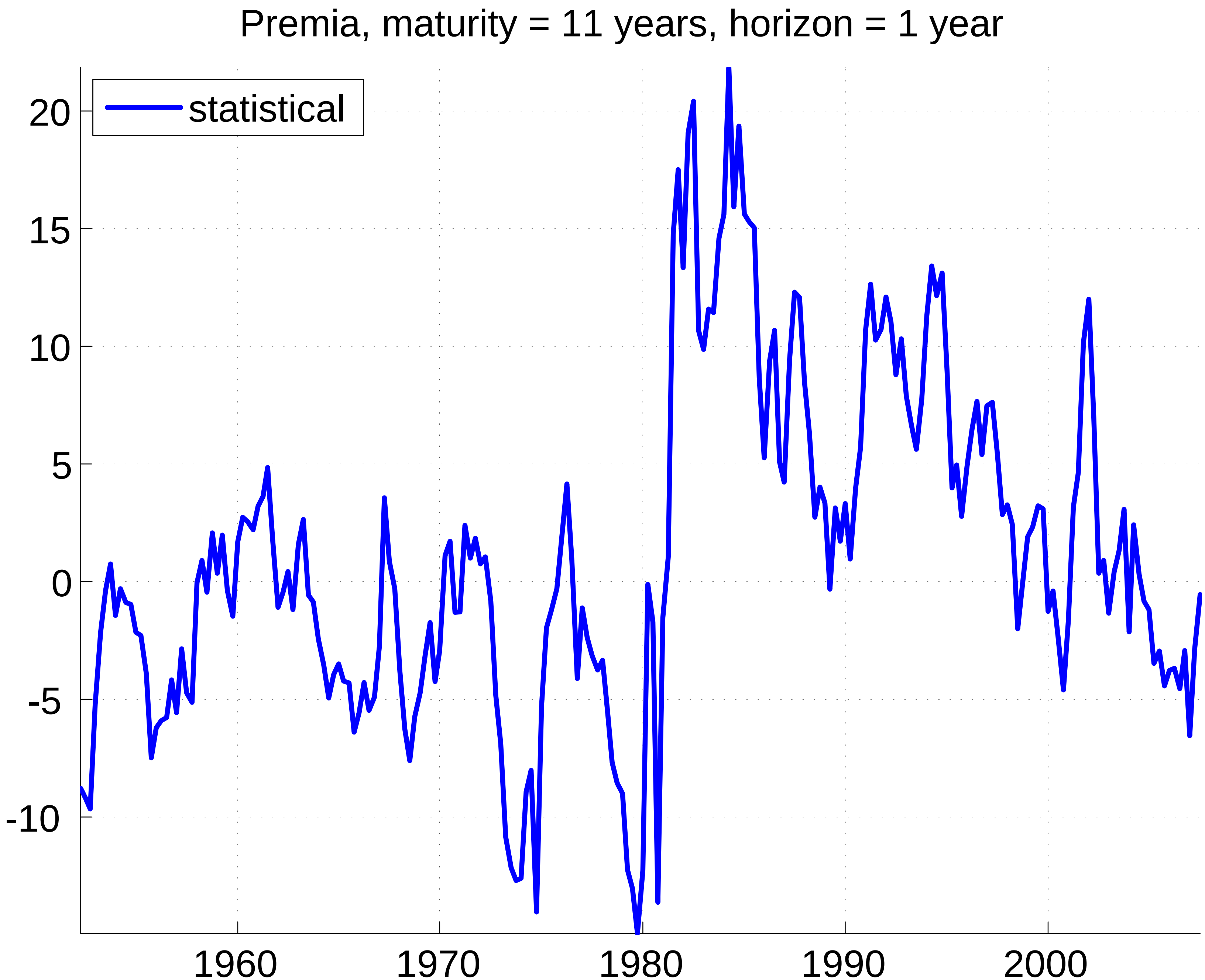
maturity 10 years

subjective premium

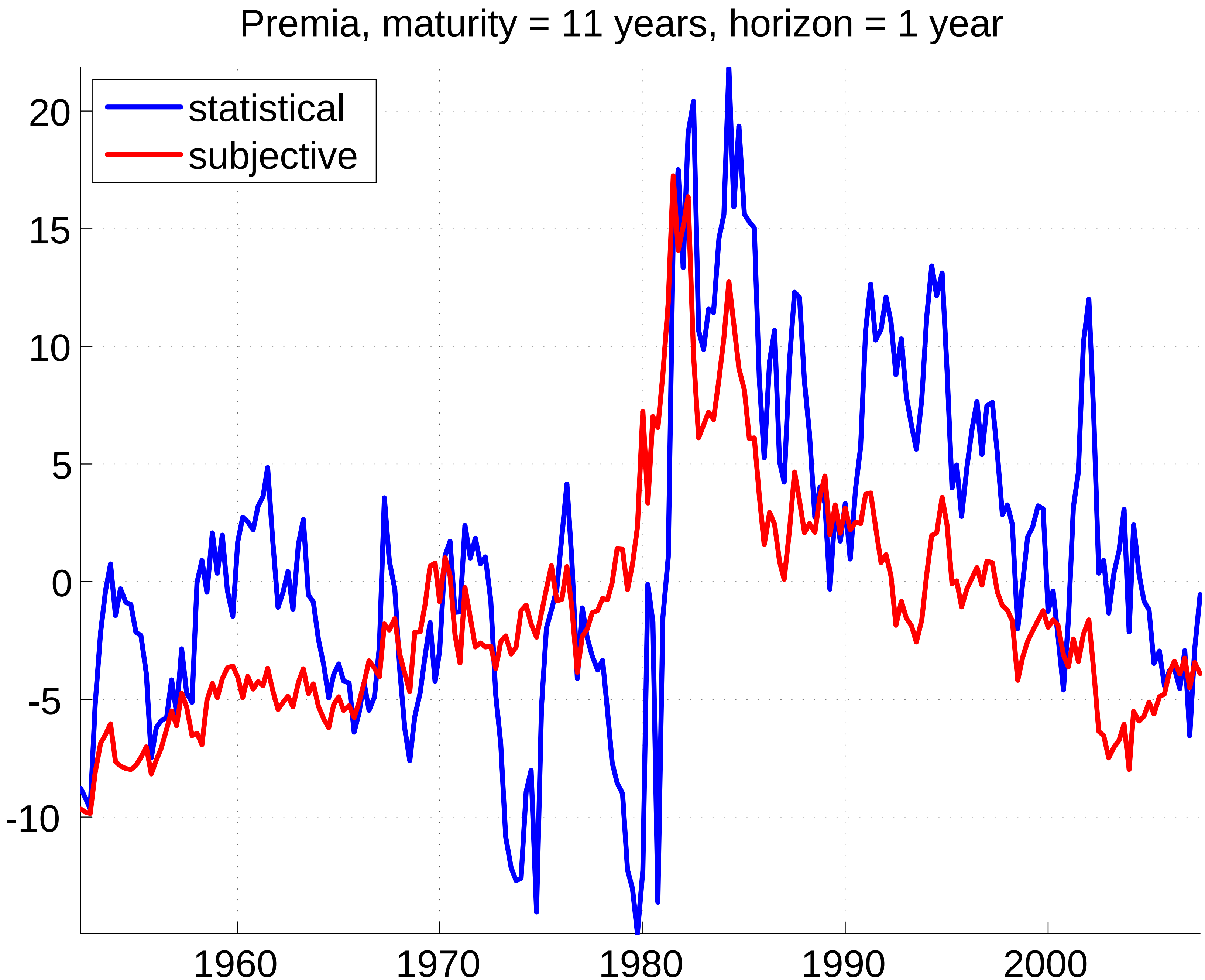
volatility	% trend	% cycle
2.96	81	15

statistical premium

6.44	94	31



Premia, maturity = 11 years, horizon = 1 year
statistical
20
15
10
5
0
-5
-10
1960
1970
1980
1990
2000


Premia, maturity = 11 years, horizon = 1 year
statistical
subjective
20
15
10
5
0
-5
-10
1960
1970
1980
1990
2000

Outline

1. Stylized facts about survey forecasts

   (a) pictures for one bond, one forecast horizon

   (b) compress info from forecasts for many maturities, horizons
   (using factor model)

$\Longrightarrow$ forecasts made as if level & slope of yield curve more persistent

$\Longrightarrow$ subjective premium much less volatile & cyclical, especially for long maturities

2. consumption based asset pricing model with learning:

   learning explains forecast differences and subjective risk premia

Consumption based asset pricing

- Beliefs: adaptive learning
  - cond. distribution of cons. growth, inflation, interest rates for every date t
  - estimate linear state space system

    (geometric downweighting of past data with forget factor υ)
  - use price variables to capture conditioning info, use in Euler equation checks

- Preferences: recursive utility (Epstein-Zin 1989)
  - special case: intertemporal elasticity of substitution $= 1$.

$$\ln V_t = (1-\beta) \ln C_t + \beta \ln \mathrm{CE}_t (V_{t+1})$$

$$\mathrm{CE}_t (V_{t+1}) = E_t \left(V_{t+1}^{1-\gamma} \right)^{1/(1-\gamma)}$$

  - aversion against persistence $\gamma > 1$

Nominal pricing kernel (in logs)

- Euler equation: for a nominal return R_{t+1}, must have $E\left[\exp\left(m_{t+1}\right)R_{t+1}\right]=1$

- With normal homoskedastic shocks, linear state space system:

$$m_{t+1} = \text{const.} \; - \; \Delta c_{t+1} - (\gamma - 1)\left(E_{t+1} - E_t\right)\sum_{\tau=1}^{\infty}\beta^{\tau}\Delta c_{t+1+\tau} - \pi_{t+1}$$

- Agents want more consumption if
  - low consumption growth
  - bad news about future consumption growth

- Agents dislike assets that pay off little if
  lo growth, hi inflation <u>or</u> bad news about growth

- Compensation for risk = Cov(return, m)
  - expected return higher if higher Cov (return, news about growth)
  - nom. n-period interest rate higher if higher Cov (inflation, news about growth)
  over lifetime of bond.

Euler equations for bonds

For a nominal return $R_{t,t+h}$, must have $E\left[\exp\left(\sum_{i=1}^{h} m_{t+i}\right) R_{t,t+h}\right] = 1$.

1. Holding period = maturity: log return = interest rate satisfies

$$i_t^{(h)} = -\frac{1}{h} E_t\left[\sum_{i=1}^{h} m_{t+i}\right] - \frac{1}{2}\frac{1}{h} Var_t\left[\sum_{i=1}^{h} m_{t+i}\right]$$

   $i_t^{(h)}$ higher if higher cov (inflation, news about growth) between t and $t+h$

2. Holding period $<$ maturity: log excess return

$$E_t\left[p_{t+h}^{(n-h)}\right] - p_t^{(n)} - h i_t^{(h)} + \frac{1}{2} Var_t\left[p_{t+h}^{(n-h)}\right] = -cov_t\left(\sum_{i=1}^{h} m_{t+i}, p_{t+h}^{(n-h)}\right)$$

   cov_t higher if higher cov ($p_{t+h}^{(n-h)}$, news about growth)

Can evaluate cond. moments under agent's subjective belief for every t & check errors

Results

Decompose statistical premium

$$\hat{E}_t rx_{t+1}^{(n)} = \left(\hat{E}_t rx_{t+1}^{(n)} - E_t rx_{t+1}^{(n)}\right) + cov_t\left(m_{t+1}, rx_{t+1}^{(n)}\right)$$

forecast difference — compensation for subjective risk

- Subjective beliefs implied by learning $\longrightarrow$ movements in forecast difference, subjective risk

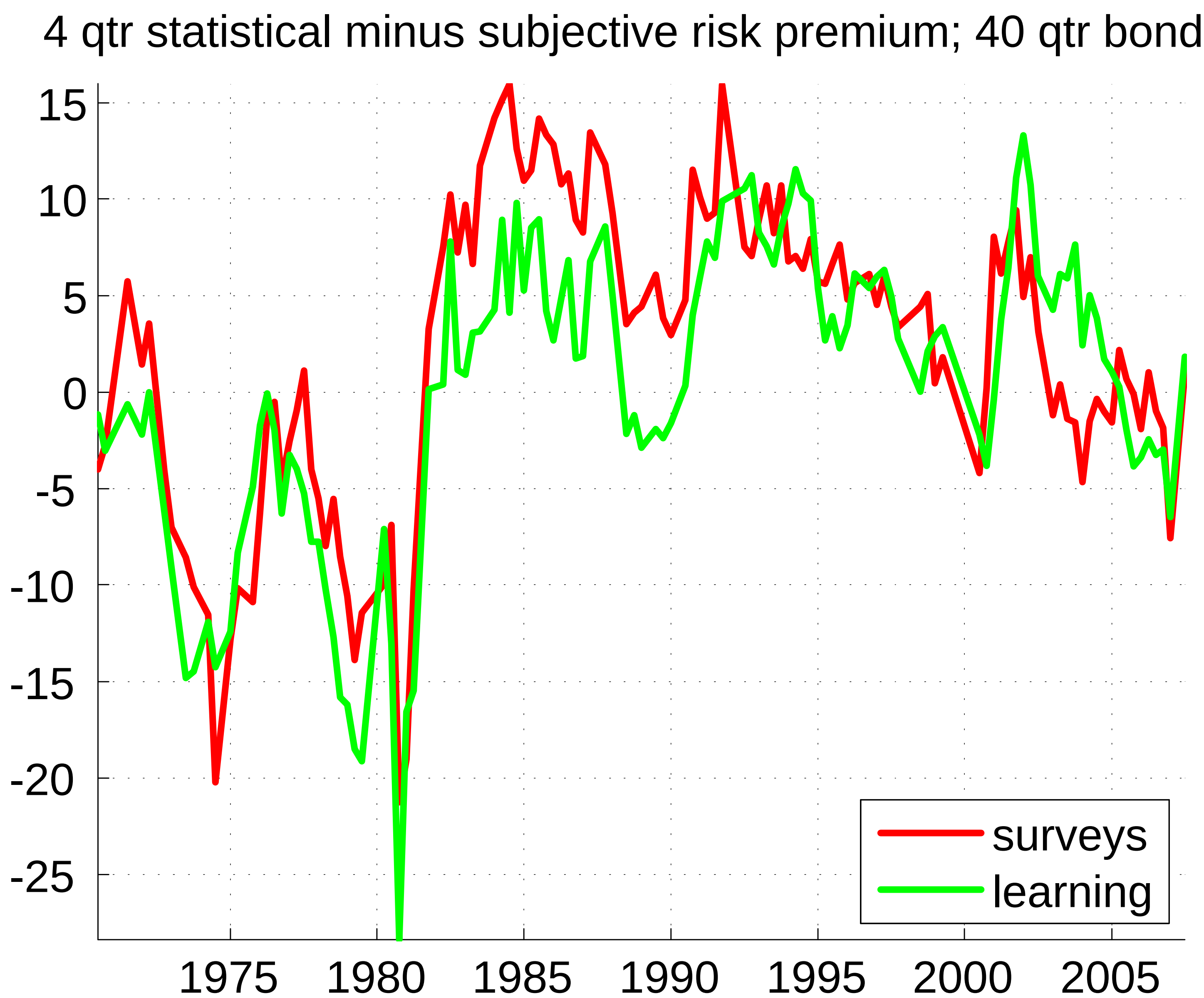
- Pick preference parameters β, γ to fit Euler equations

- Time variation in subjective, statistical risk premia

Results: subjective beliefs from learning

- Forecasts
  - fit survey forecasts better than statistical model
    (MAE drops for most forecast horizons, maturities)
  - forecast differences:
    (statistical minus surveys) versus (statistical minus learning):
    learning tracks change in sign around 1980, many cyclical movements
- Subjective Risk
  - Cov_t (bond price, news about growth) high & positive after 70s, negative later
  - Cov_t (inflation, news about growth) high after 70s, lower later

Forecast differences



Preference parameters

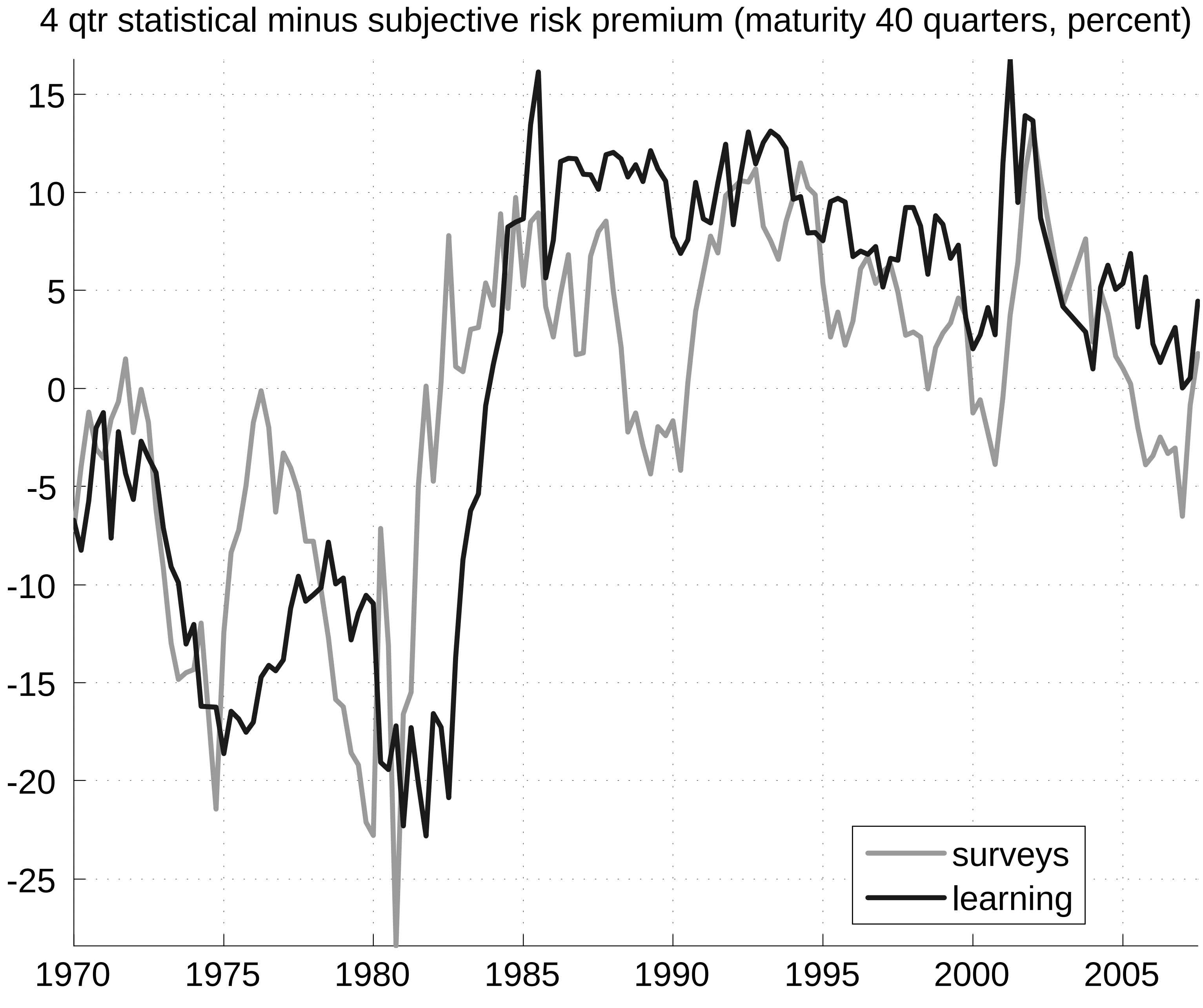
- Horizon $h = 4$ quarters.
- Consider three Euler equations
  - 4 and 40 quarter interest rate
  - excess return for holding 40 quarter bond over 4 quarters (express in terms of forward rates)
- Select β, γ to match equally weighted sum of squared errors
- For comparison, use statistical model as belief, and log utility

Euler equation errors

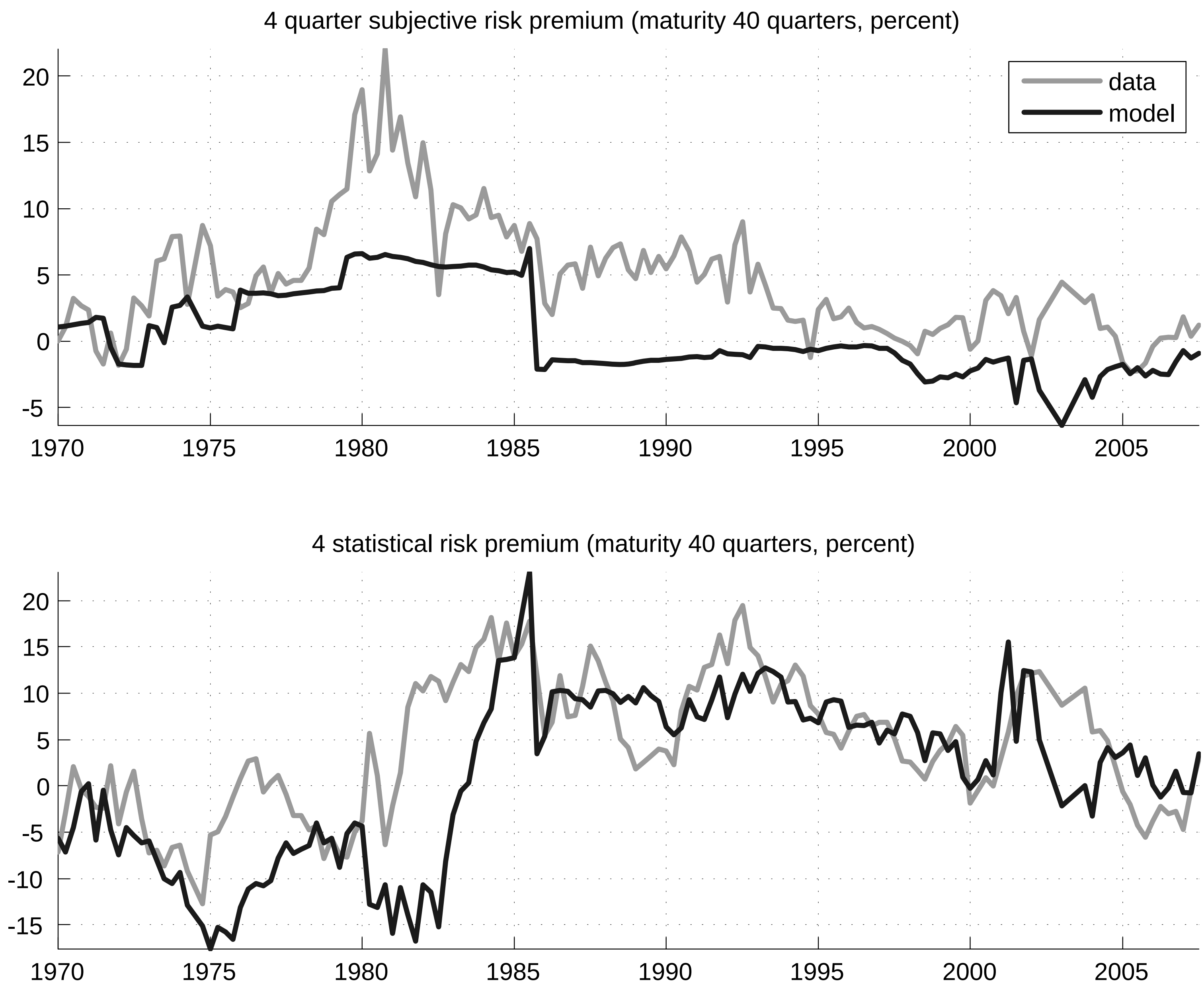
Table 8: Euler Equations Errors

model	Preferences		Euler equation errors Mean absolute error (% p.a.)		
	β	γ	$i_t^{(4)}$	$i_t^{(40)}$	$f_t^{(36,4)}$
statistical belief					
log utility	.9970	1	1.97	1.70	0.83
Epstein-Zin	.9961	26	1.96	1.69	0.86
learning $\upsilon = .95$					
Epstein-Zin	.9966	80	1.76	1.21	0.62

Forecast differences



Subjective and Statistical Risk Premia



Message

- decompose statistical premium

$$\hat{E}_t rx_{t+1}^{(n)} = \underbrace{\left(\hat{E}_t rx_{t+1}^{(n)} - E_t rx_{t+1}^{(n)}\right)}_{\text{forecast difference}} + \underbrace{cov_t\left(m_{t+1}, rx_{t+1}^{(n)}\right)}_{\text{subjective risk premium}}$$

- Movements in forecast difference
  - forecasts lag behind trends, do not react much to sudden changes

$\Longrightarrow$ forecast differences low in 70s, high in 80s, countercyclical.

- Movements in (subjective) risk premium
  - with recursive utility, Cov (returns, news about growth) drives premia
  - high interest rates, inflation bad news for growth, more so after 1970s

$\Longrightarrow$ subjective premium slow-moving, high in 80s