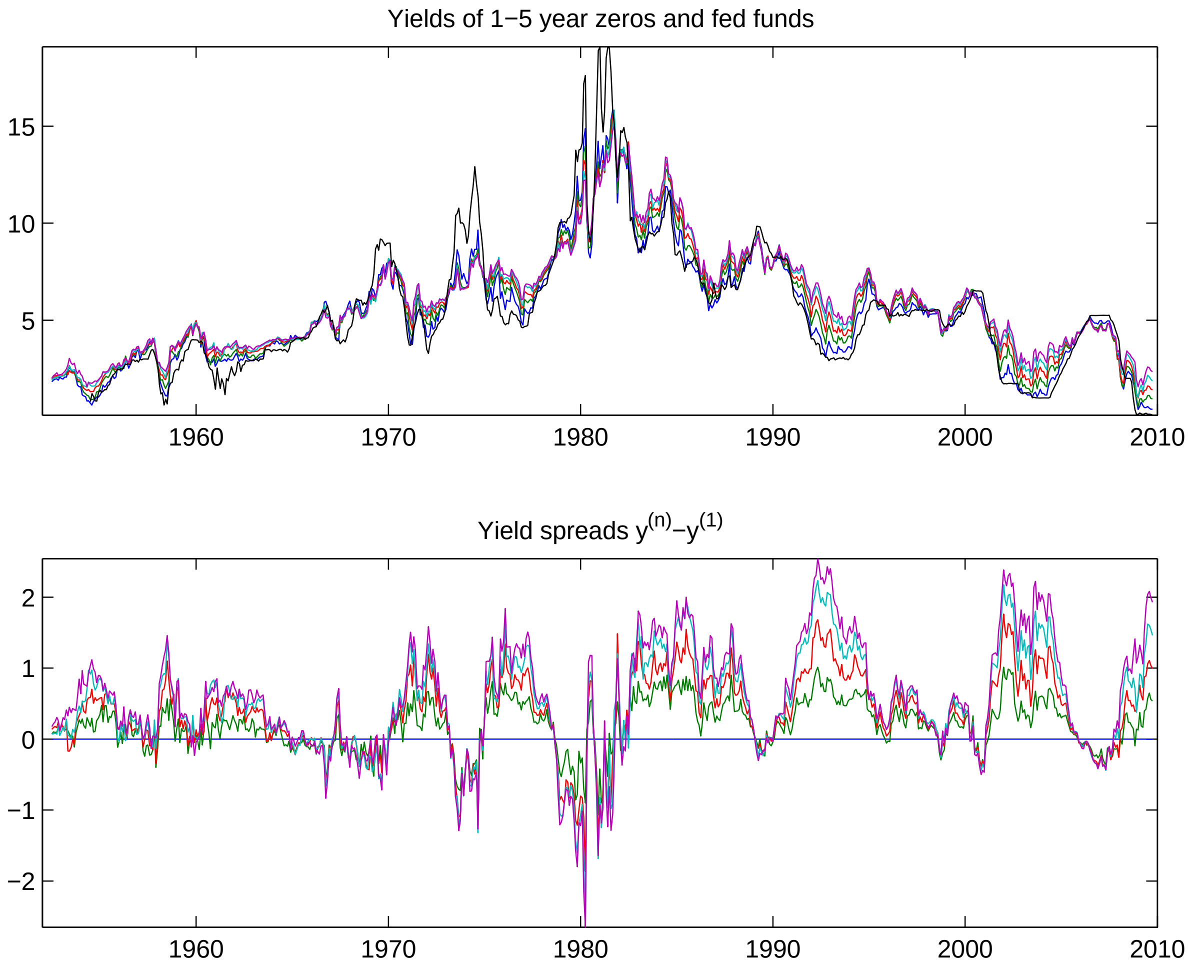
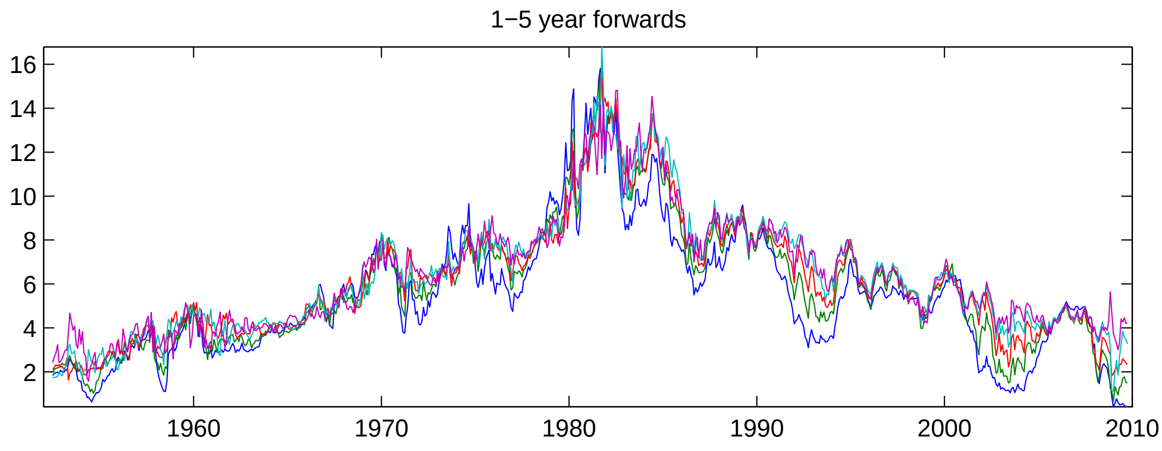
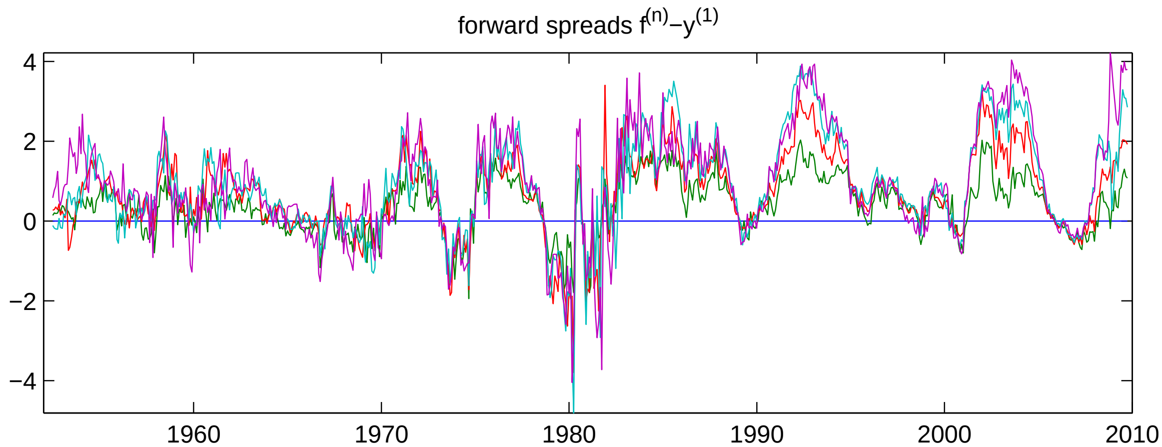
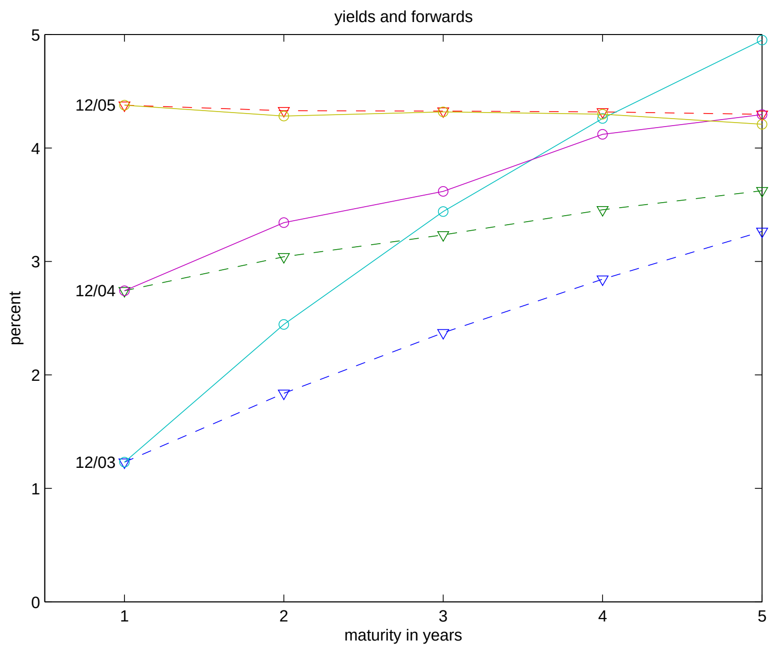
Term structure




1−5 year forwards
16
14
12
10
8
6
4
2
1960
1970
1980
1990
2000
2010


forward spreads $f^{(n)}-y^{(1)}$
4
2
0
−2
−4
1960
1970
1980
1990
2000
2010

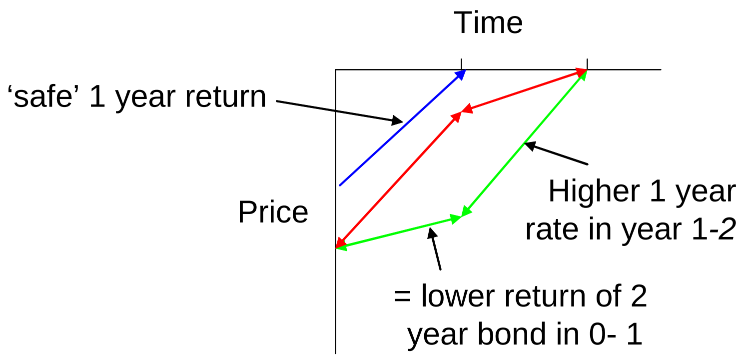

yields and forwards
12/05
12/04
12/03
percent
maturity in years
0
1
2
3
4
5

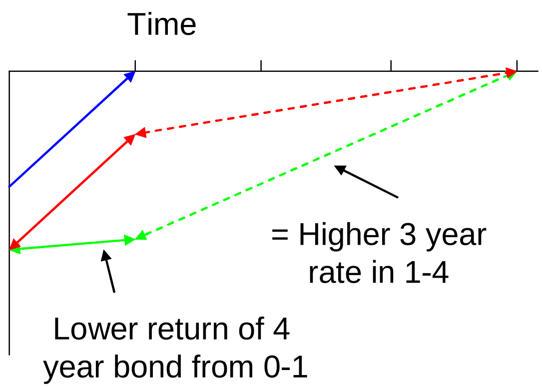
Asset Pricing Table 20.8 Update

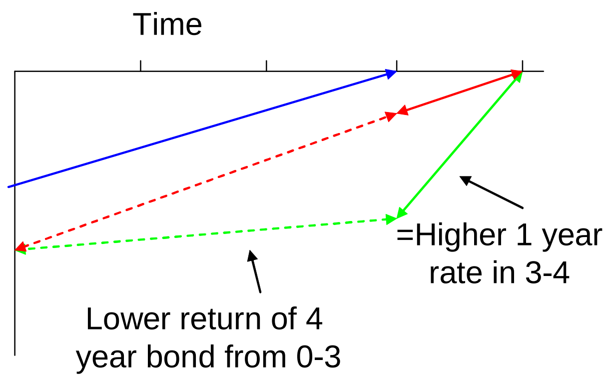
Interest rate data 1964:01-2008:12					
Maturity n	1	2	3	4	5
$E\left[y^{(n)}\right]$	6.16	6.37	6.54	6.68	6.76
$E\left[y^{(n)}-y^{(1)}\right]$	0	0.21	0.38	0.51	0.59
$E\left[r^{(n)}-y^{(1)}\right]$	0	0.46	0.80	1.38	1.05
$\sigma\left[r^{(n)}-y^{(n)}\right]$	0	1.87	3.42	4.73	5.79
"Sharpe"	0	0.25	0.23	0.22	0.18

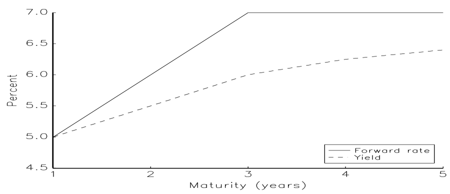
Asset Pricing Table 20.9 p. 428. Updated

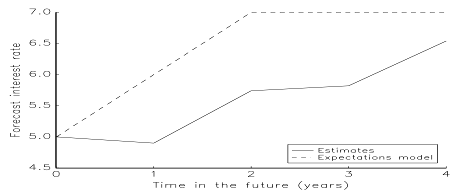
	$rx_{t+1}^{(n)} = a+b\left(f_t^{(n)}-y_t^{(1)}\right)+\varepsilon_{t+1}$			$y_{t+n-1}^{(1)}-y_t^{(1)} = a+b\left(f_t^{(n)}-y_t^{(1)}\right)+\varepsilon_{t+1}$			
n	b	$\sigma(b)$	R^2	a	b	$\sigma(b)$	R^2
2	0.83	0.27	0.12		0.17	0.27	0.01
3	1.12	0.36	0.13		0.47	0.31	0.04
4	1.34	0.45	0.14		0.75	0.23	0.12
5	1.02	0.52	0.06		0.87	0.16	0.16
	forecasting *one* year returns on n-year bonds			forecasting *one* year rates n years from now			



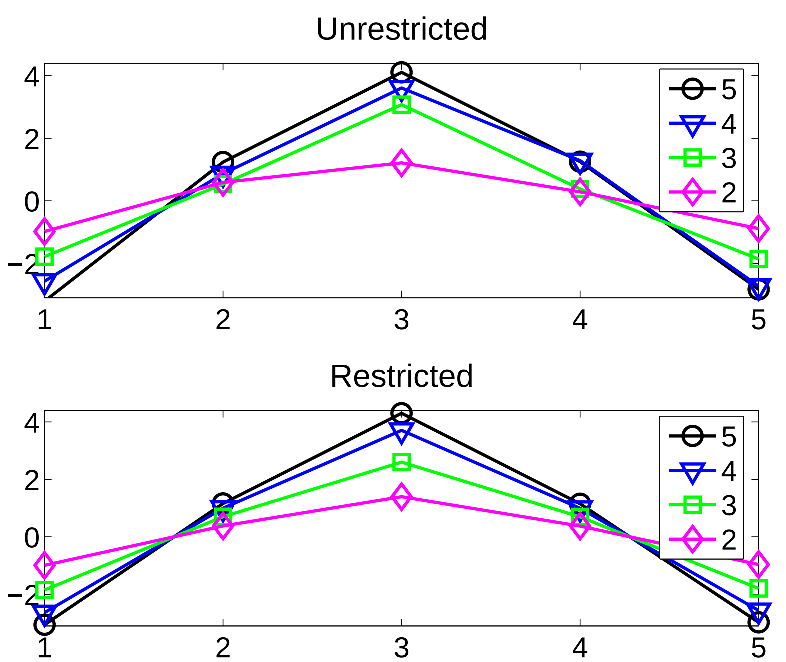








Cochrane-Piazzesi



$$rx_{t+1}^{(n)} = a_n + b_1 y_t^{(1)} + b_2 f_t^{(2)} + ... + b_5 f_t^{(5)} + \varepsilon_{t+1}^{(n)}$$

$$rx_{t+1}^{(n)} = b_n \left(\gamma^\top f_t\right) + \varepsilon_{t+1}^{(n)}$$

Results:

Table 1 Estimates of the single-factor model

A. Estimates of the return-forecasting factor, $\overline{rx}_{t+1} = \gamma^\top f_t + \bar{\varepsilon}_{t+1}$

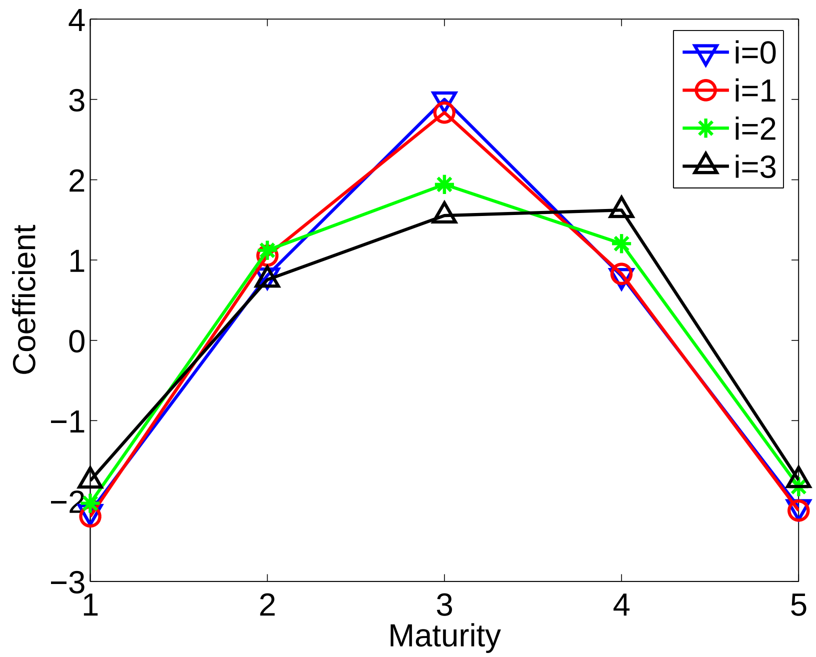
	γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	R^2	$\chi^2(5)$
OLS estimates	−3.24	−2.14	0.81	3.00	0.80	−2.08	0.35	105.5

B. Individual-bond regressions

	Restricted		Unrestricted	
	$rx^{(n)}_{t+1} = b_n \left(\gamma^\top f_t\right) + \varepsilon^{(n)}_{t+1}$		$rx^{(n)}_{t+1} = \beta_n f_t + \varepsilon^{(n)}_{t+1}$	
n	b_n	R^2	R^2	$\chi^2(5)$
2	0.47	0.31	0.32	121.8
3	0.87	0.34	0.34	113.8
4	1.24	0.37	0.37	115.7
5	1.43	0.34	0.35	88.2

- A *single factor model for expected returns.* $Cov(E_t rx_{t+1}) = bb'var(x_t)$ $x_t = \gamma' f_t$(4x4) has a strong single-factor structure
- Coefficients are not the FB pattern. R^2 a good deal better than Fama-Bliss~0.15.

Measurement error and moving averages



$$rx_{t+1} = a + \gamma' \left(f_t + f_{t-1} + f_{t-2} + ...\right) \varepsilon_{t+1}$$

k	1	2	3	4	6
R^2	0.35	0.41	0.43	0.44	0.43

(Compare to FB 0.15 R^2)

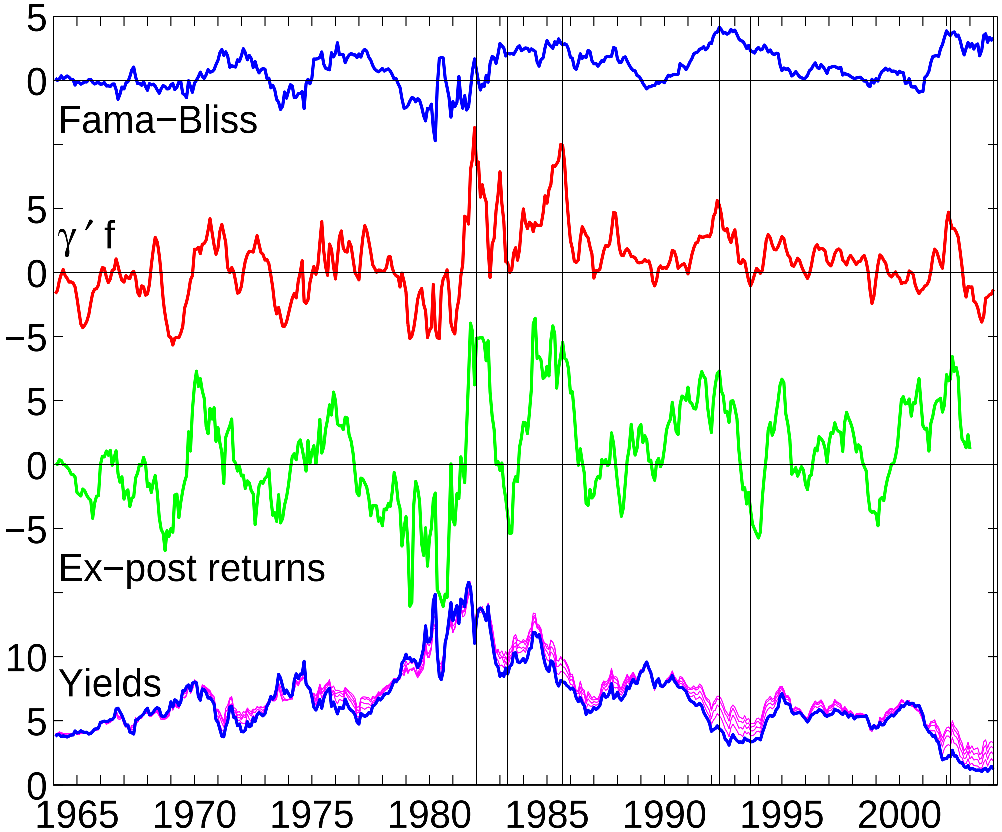
Stock return forecasts

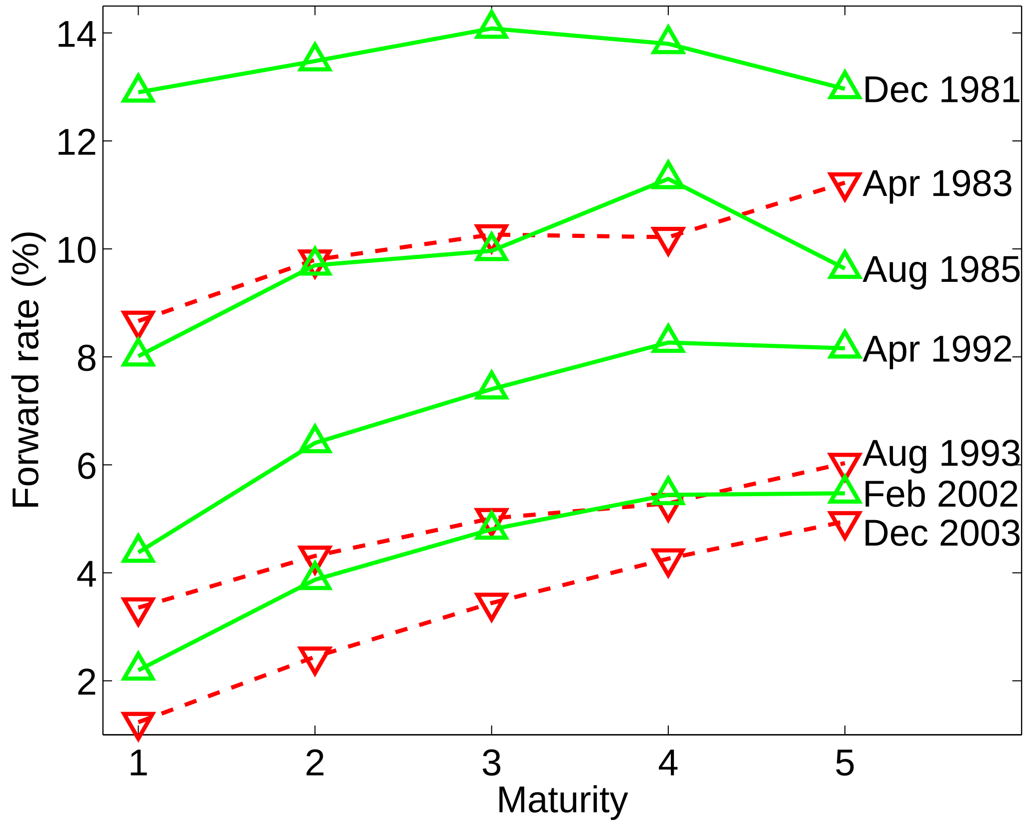
Table 3. Forecasts of excess stock returns (VWNYSE)

$$\overline{rx}_{t+1} = a + bx_t + \varepsilon_{t+1}$$

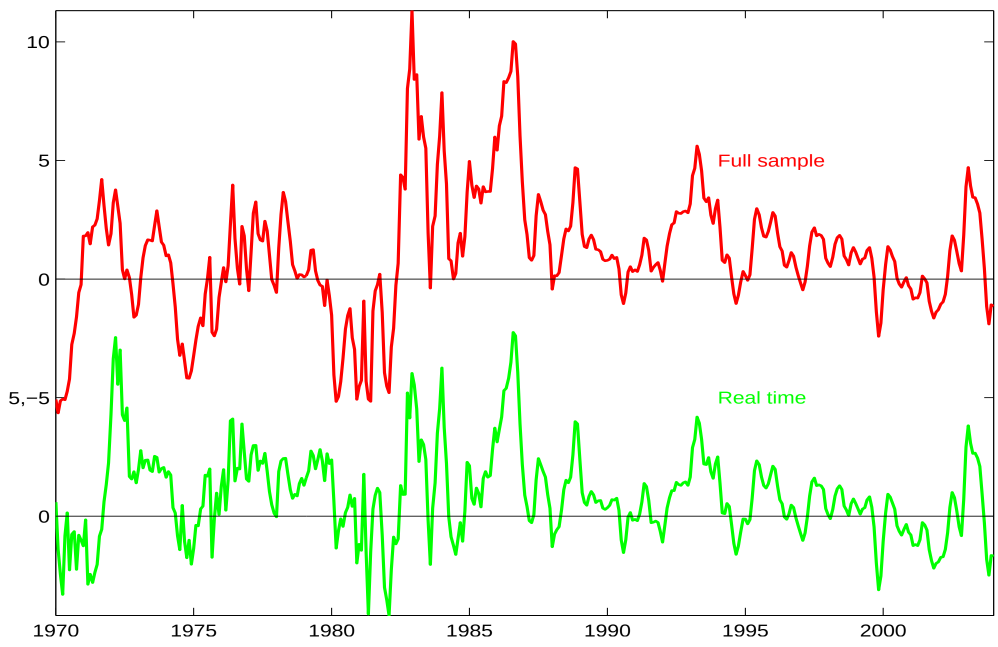
	$\gamma^\top f$	(t)	D/P	(t)	$y^{(5)} - y^{(1)}$	(t)	R^2
	1.73	(2.20)					0.07
			3.56	(1.80)	3.29	(1.48)	0.08
	1.87	(2.38)			−0.58	(−0.20)	0.07
	1.49	(2.17)	2.64	(1.39)			0.10
MA $\gamma^\top f$	2.11	(3.39)					0.12
MA $\gamma^\top f$	2.23	(3.86)	1.95	(1.02)	−1.41	(−0.63)	0.15

Is it real or just a few data points? What is the story?

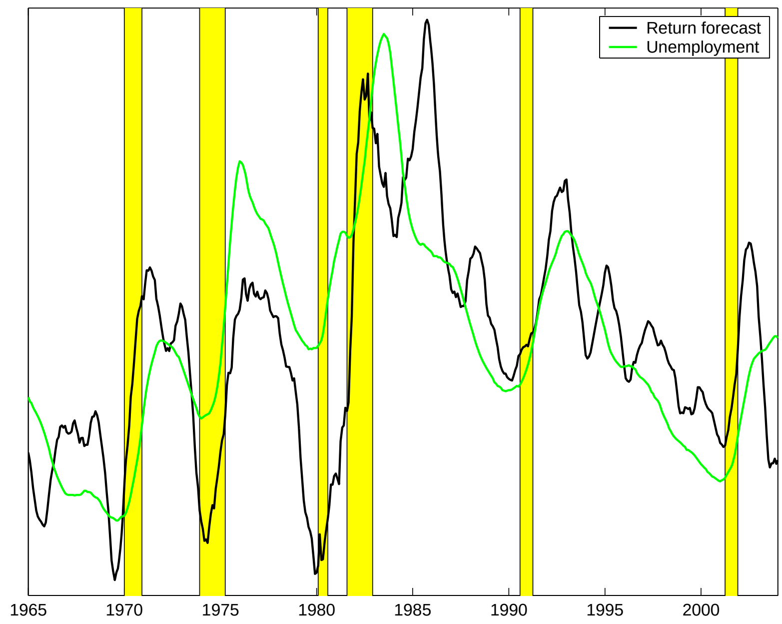




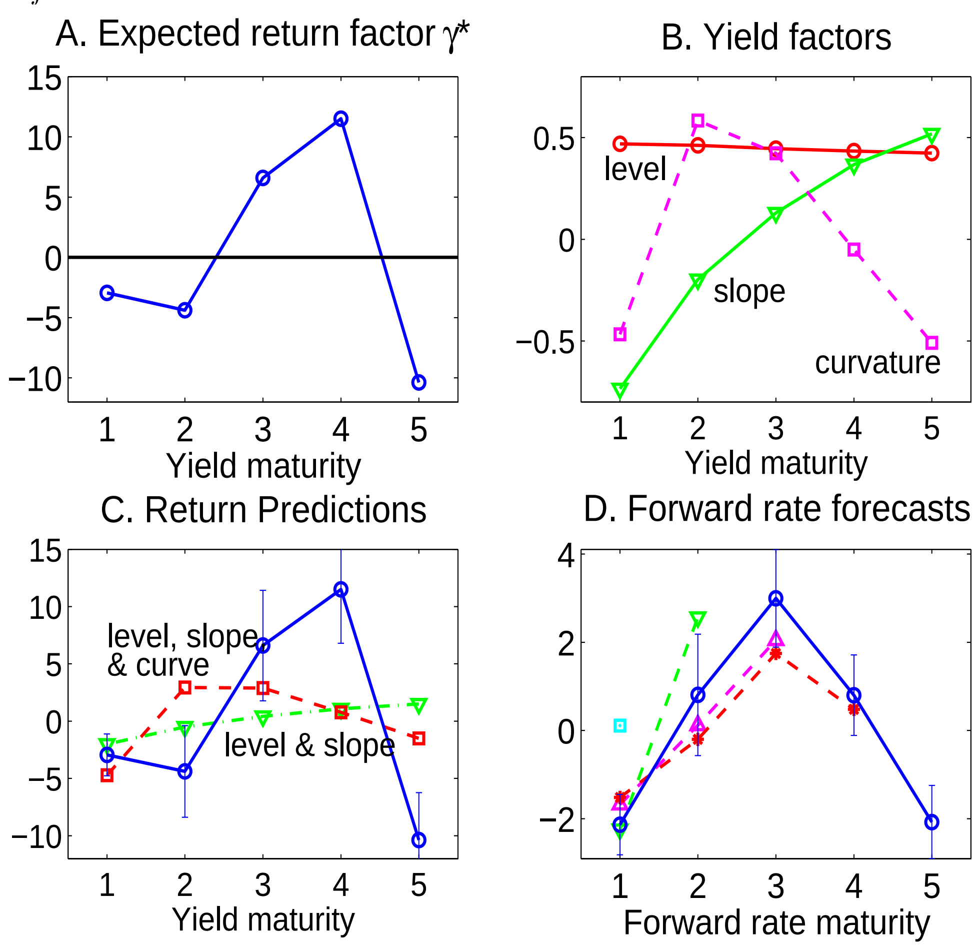
Forward rate (%)
Maturity
Dec 1981
Apr 1983
Aug 1985
Apr 1992
Aug 1993
Feb 2002
Dec 2003



Full sample
Real time



Yield curve factor models.



Lesson.

1. *First* smooth, *then* forecast can throw out the baby with the bathwater.
2. "maximize variance of yields, returns, etc." is not "maximize variance of expected returns"
3. Expected returns are (nearly) "unspanned state variables" a big new issues

Failure of GMM.

$$rx_{t+1}^{(2)} - b_2 \overline{rx}_{t+1} = a^{(2)} + 0' f_t + \varepsilon_{t+1} = a^{(2)} + 0' y_t + \varepsilon_{t+1}$$

(Why?

$$\begin{aligned} rx_{t+1}^{(2)} &= \alpha^{(2)} + b_2 \left(\gamma' f_t\right) + \varepsilon_{t+1}^{(2)} \\ \overline{rx}_{t+1} &= \alpha + \gamma' f_t + \varepsilon_{t+1}^{(2)} \end{aligned}$$

multiply the second by b_2 and subtract.)

Table 7. Forecasting the failures of the single-factor model
A. Coefficients and t-statistics

		Right hand variable				
Left hand var.	const.	$y_t^{(1)}$	$y_t^{(2)}$	$y_t^{(3)}$	$y_t^{(4)}$	$y_t^{(5)}$
$rx_{t+1}^{(2)} - b_2 \overline{rx}_{t+1}$	−0.11	−0.20	**0.80**	−0.30	−0.66	0.40
(t-stat)	(−0.75)	(−1.43)	**(2.19)**	(−0.90)	(−1.94)	(1.68)
$rx_{t+1}^{(3)} - b_3 \overline{rx}_{t+1}$	0.14	0.23	−1.28	**2.36**	−1.01	−0.30
(t-stat)	(1.62)	(2.22)	(−5.29)	**(11.24)**	(−4.97)	(−2.26)
$rx_{t+1}^{(4)} - b_4 \overline{rx}_{t+1}$	0.21	0.20	−0.06	−1.18	**1.84**	−0.82
(t-stat)	(2.33)	(2.39)	(−0.33)	(−8.45)	**(9.13)**	(−5.48)
$rx_{t+1}^{(5)} - b_5 \overline{rx}_{t+1}$	−0.24	−0.23	0.55	−0.88	−0.17	**0.72**
(t-stat)	(−1.14)	(−1.06)	(1.14)	(−2.01)	(−0.42)	**(2.61)**

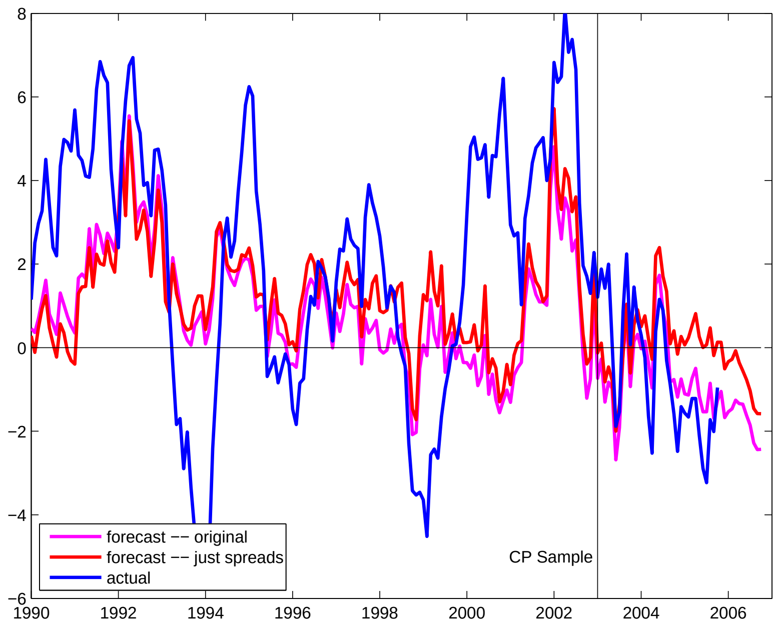
B. Regression statistics

Left hand var.	R^2	$\chi^2(5)$	$\sigma(\tilde{\gamma}^\top y)$	$\sigma(\text{lhs})$	$\sigma(b^{(n)}\gamma^\top y)$	$\sigma(rx_{t+1}^{(n)})$
$rx_{t+1}^{(2)} - b_2 \overline{rx}_{t+1}$	0.15	41	0.17	0.43	1.12	1.93
$rx_{t+1}^{(3)} - b_3 \overline{rx}_{t+1}$	0.37	151	0.21	0.34	2.09	3.53
$rx_{t+1}^{(4)} - b_4 \overline{rx}_{t+1}$	0.33	193	0.18	0.30	2.98	4.90
$rx_{t+1}^{(5)} - b_5 \overline{rx}_{t+1}$	0.12	32	0.21	0.61	3.45	6.00

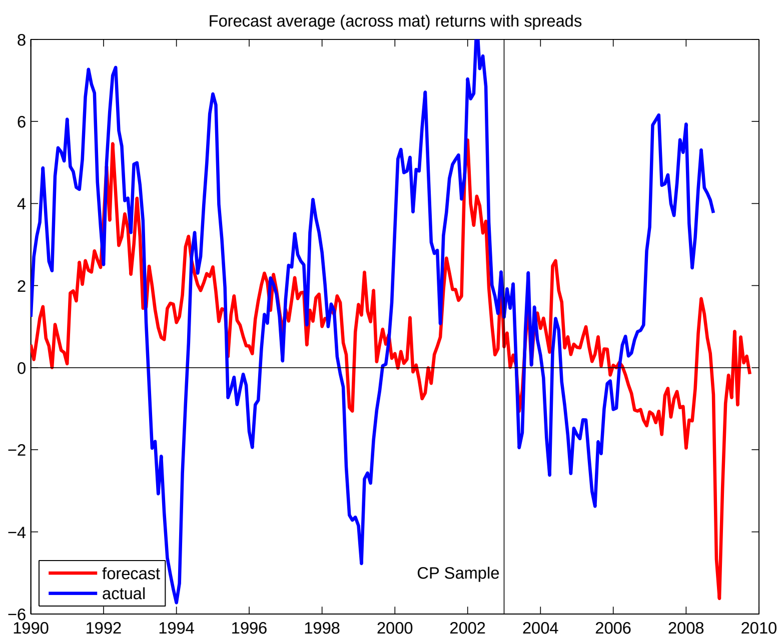
Measurement error, ϕ^{12},

(See paper)

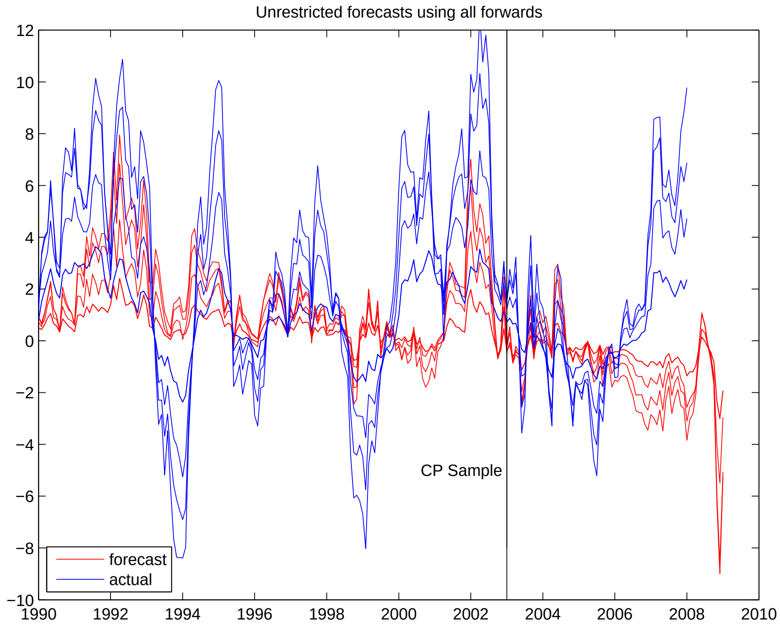
Latest data, and treasury curves during the crash



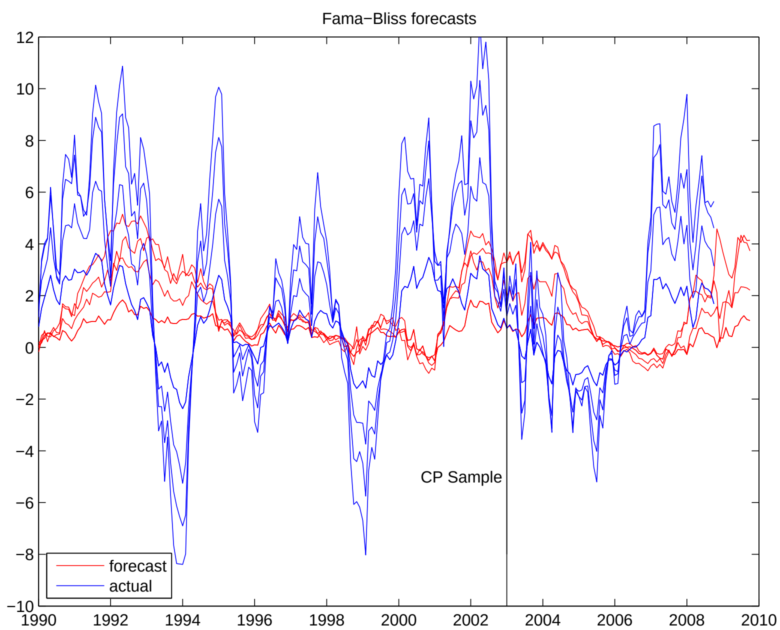
Last time I looked we were doing pretty well out of sample.



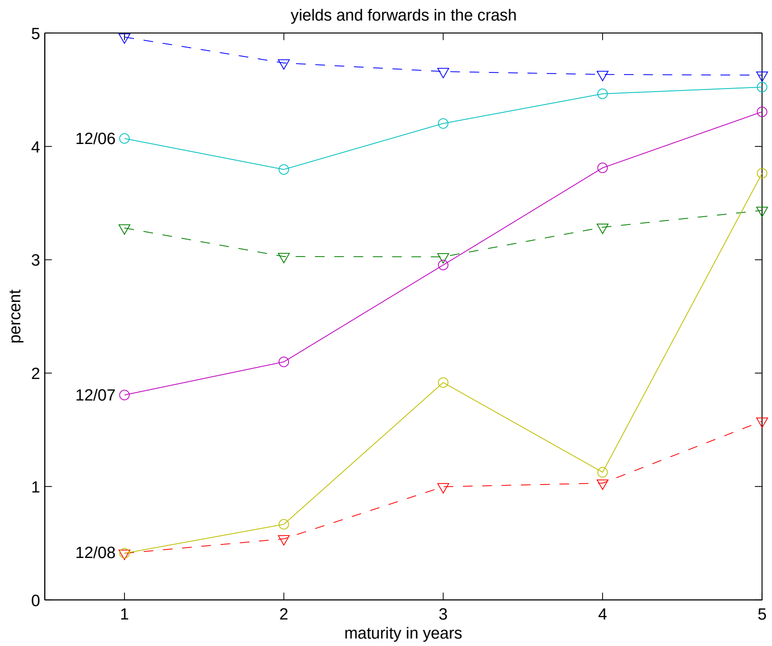
Now alas it doesn't look so good! We missed the big decline in rates in 2008 and what's that wild stuff at the end?:

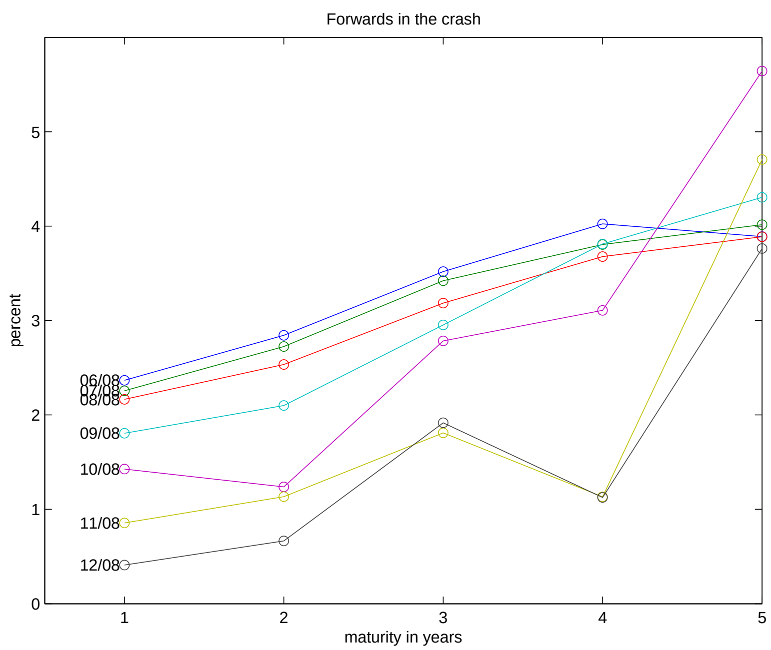


Here are the unrestricted regression forecasts – each bond on all forward rates. This just shows how it works with no processing or anything.

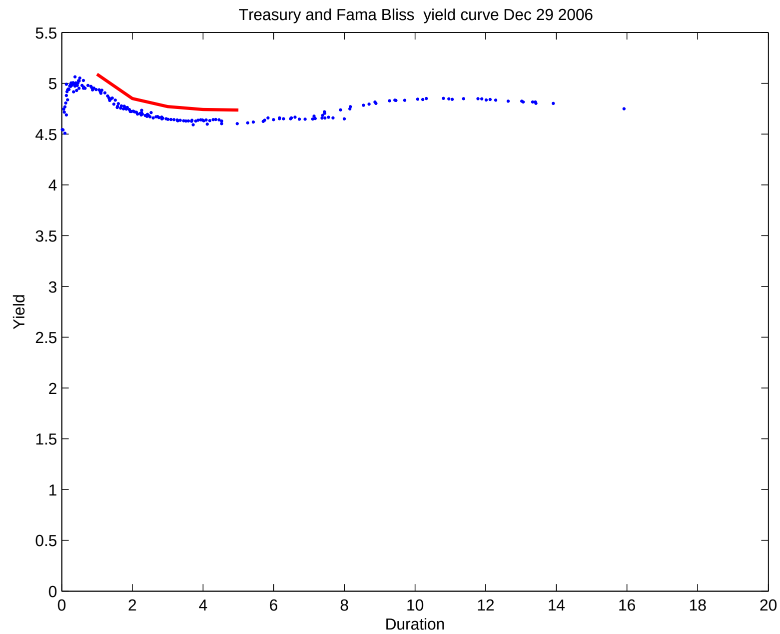


Of course, Fama-Bliss isn't doing a whole lot better

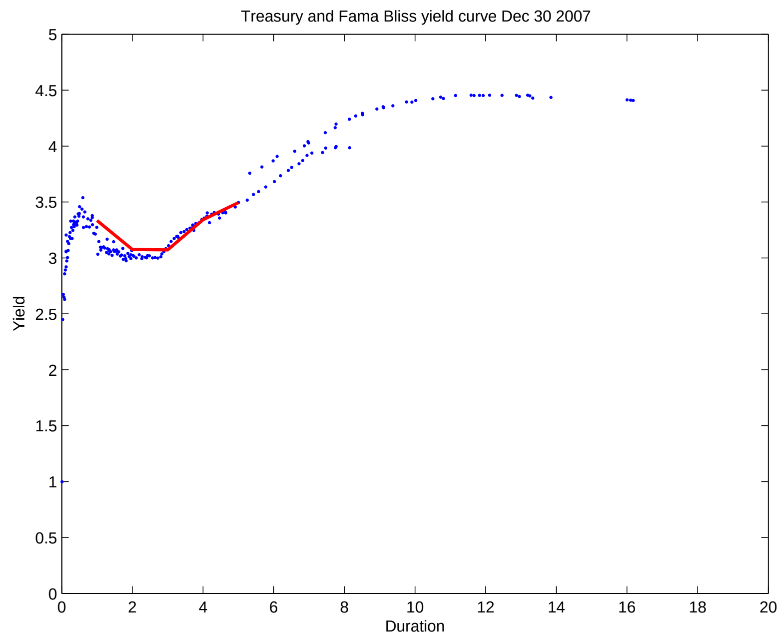




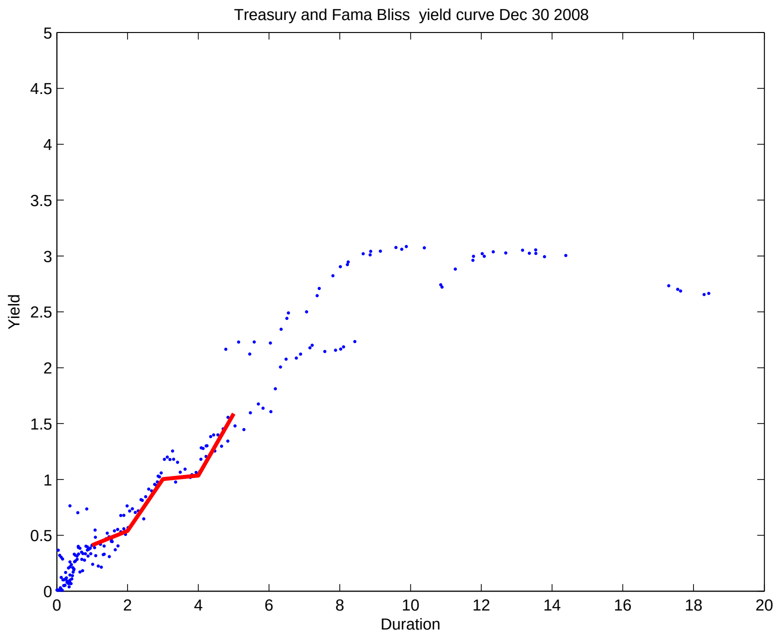
I think the recent weirdness comes down to recent weirdness in the treasury yield curve. In 2008 there was a huge demand for treasuries that can be repoed to finance other positions. And much less demand for other issues. This ledto very weird treasury yield curves, which I think are beyond the FB data construction technique to make sense of .



Here are the underlying data. Each bond is a blue dot. The red line is the FB fit to the yield curve. In 06 it was all sensible



In Dec 07 things were getting worse. The massive upward curve causes the CP factor to say returns should be extremely negative.

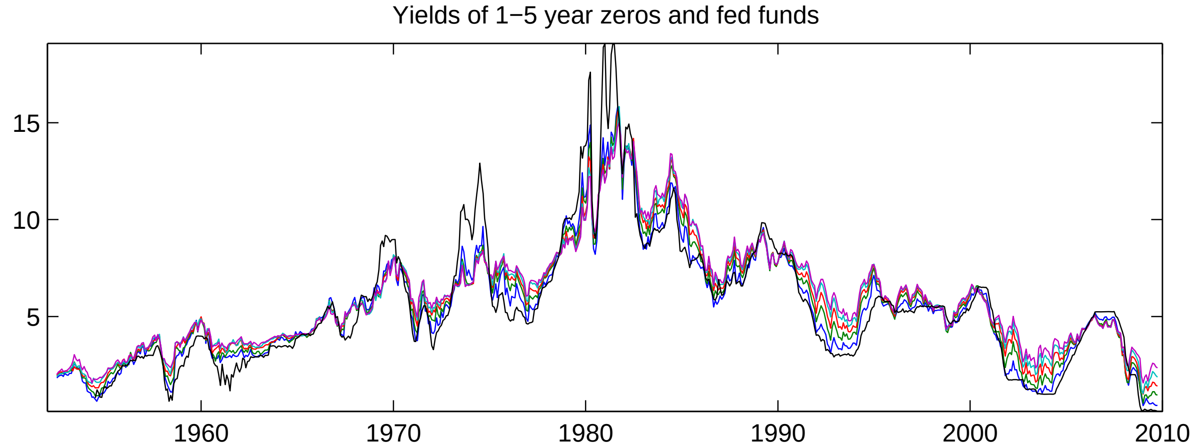


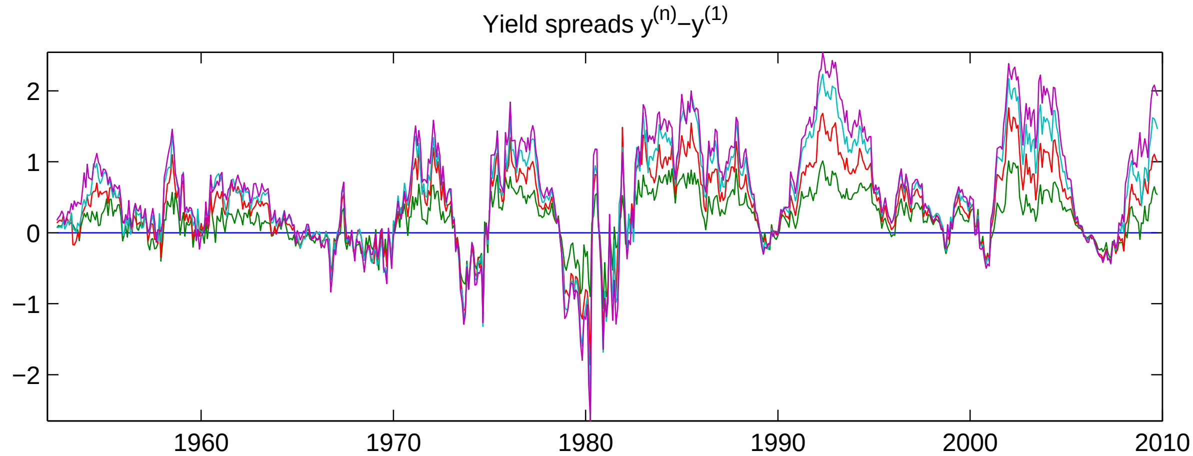
In Dec 2008 it's just a mess. The zig zag in yields gives rise to the weird forward rate pattern. Look at these huge spreads for bonds of the same duration! I think that's the on the run (and deliverable to short/repo) vs. off the run spread.

Agenda: DATA! Get away from using someone else's interpolated zero curve, and estimate/evaluate term structure models directly on the underlying data.

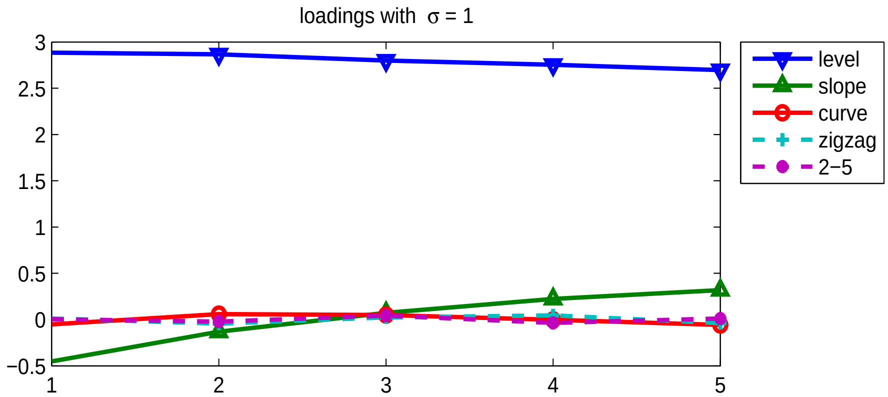
(Not so easy as "use swap data." That has issues too, and a long time span is really useful for risk premium estimation!)

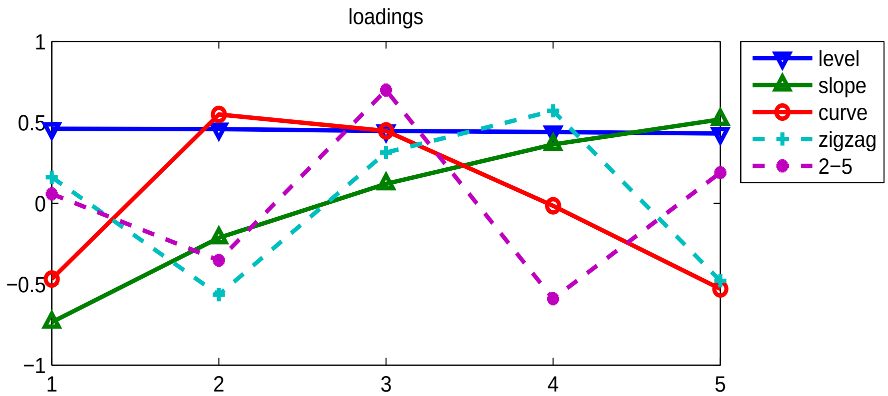
Statistical factor models

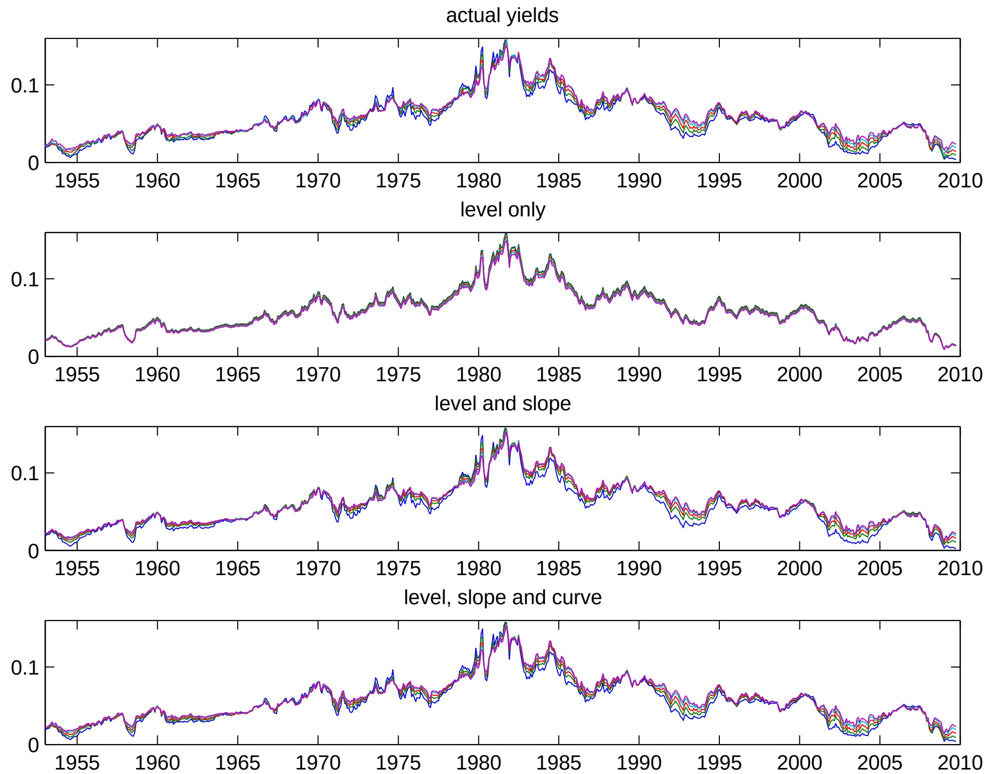


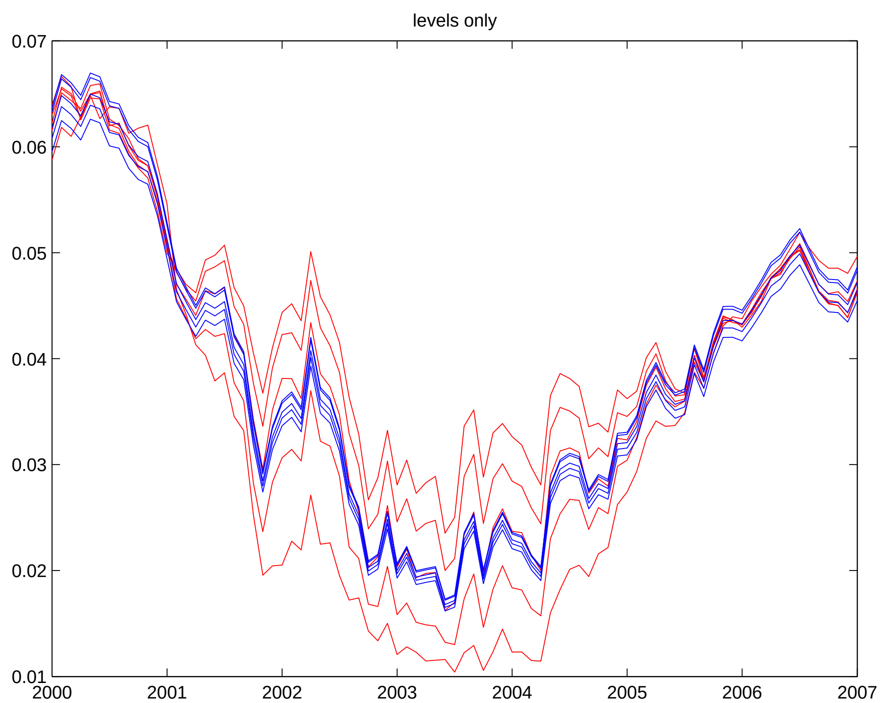


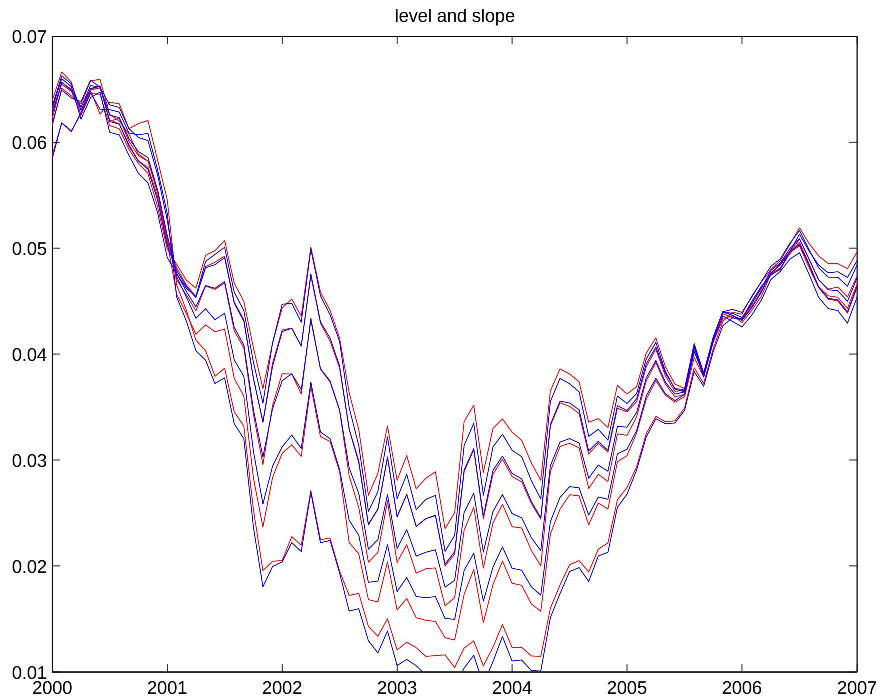

```
Sigma = cov(100*yields);
[Q,L] = eig(Sigma);
disp(diag(L)'.^0.5);
%(my names)2-5           zigzag         curve          slope          level
          0.06           0.07           0.10           0.58           5.80
disp(Q)
          0.06           0.15          -0.47          -0.74           0.46
         -0.35          -0.55           0.56          -0.21           0.46
          0.70           0.32           0.44           0.12           0.45
         -0.59           0.57          -0.03           0.36           0.44
          0.19          -0.49          -0.52           0.51           0.43
loads = Q*L^0.5;
plot(loads)
plot(Q)
```

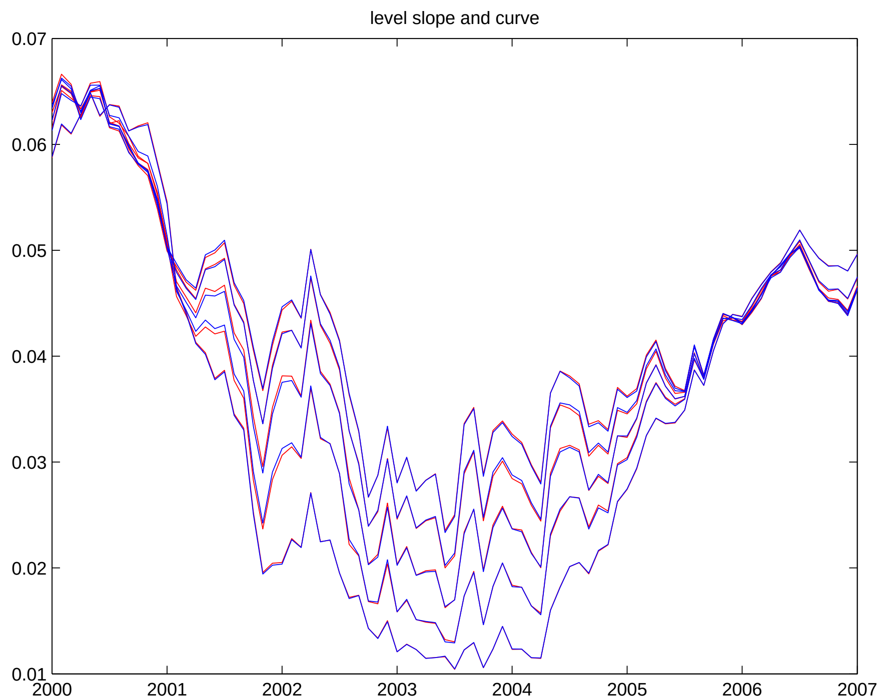

loadings with σ = 1
3
2.5
2
1.5
1
0.5
0
−0.5
1
2
3
4
5
level
slope
curve
zigzag
2−5


loadings
1
0.5
0
−0.5
−1
1
2
3
4
5
level
slope
curve
zigzag
2−5

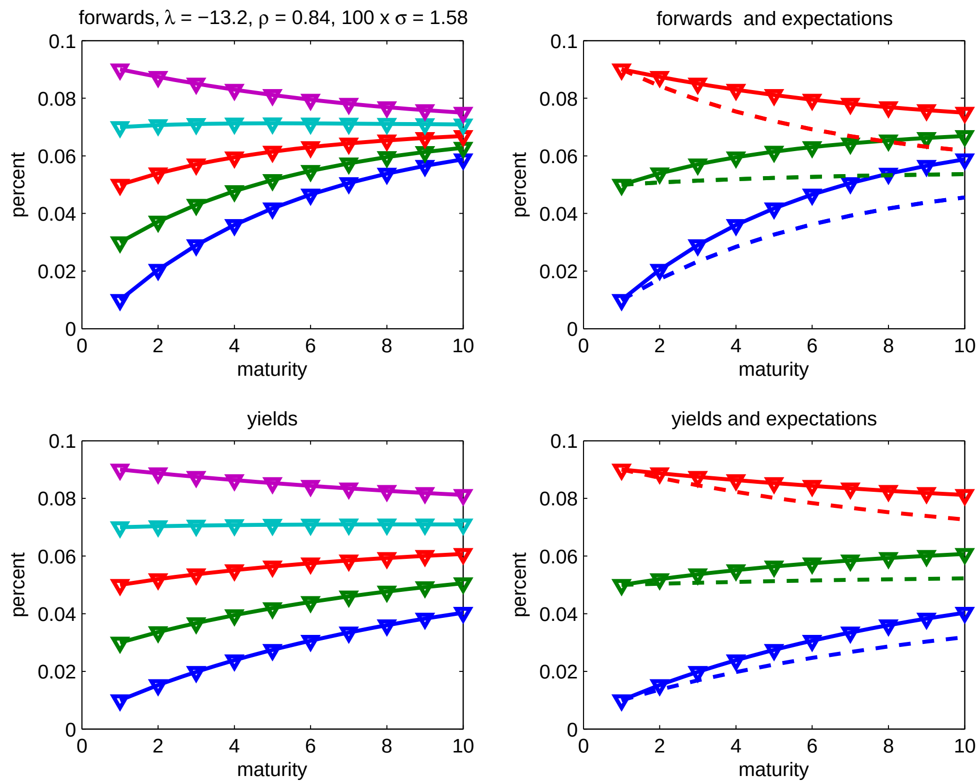

actual yields
level only
level and slope
level, slope and curve
0.1
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

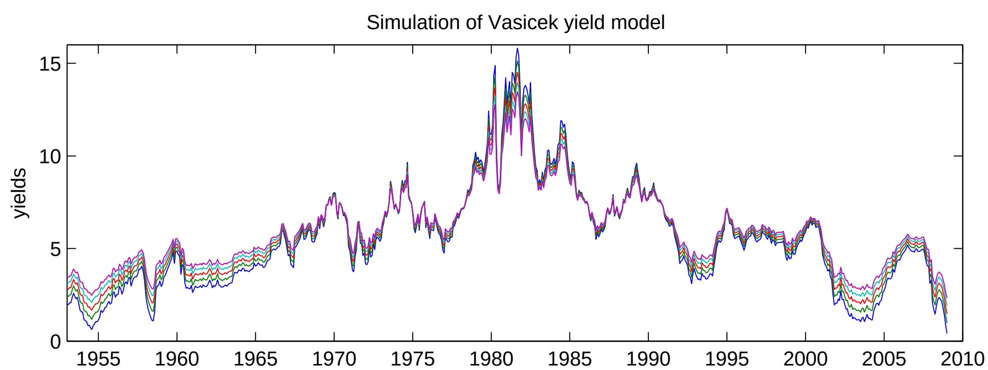

levels only
0.07
0.06
0.05
0.04
0.03
0.02
0.01
2000
2001
2002
2003
2004
2005
2006
2007

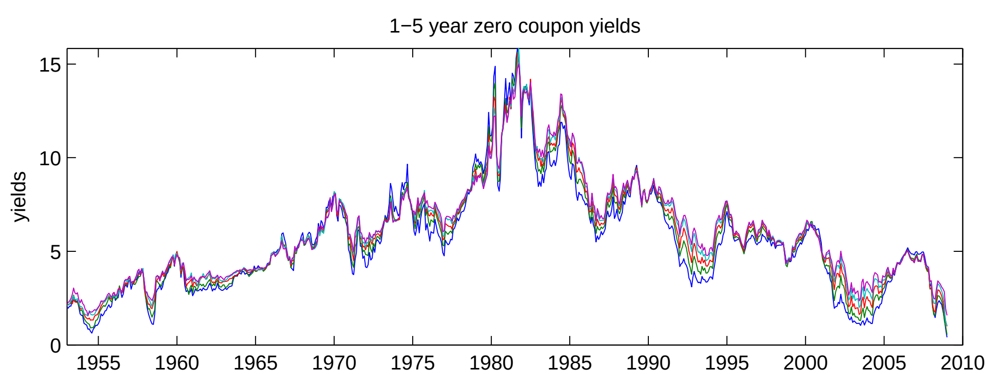

level and slope
0.07
0.06
0.05
0.04
0.03
0.02
0.01
2000
2001
2002
2003
2004
2005
2006
2007

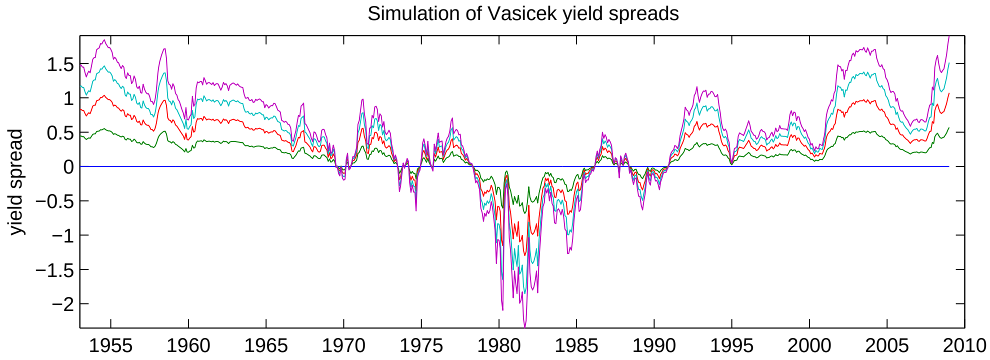

level slope and curve
0.07
0.06
0.05
0.04
0.03
0.02
0.01
2000
2001
2002
2003
2004
2005
2006
2007

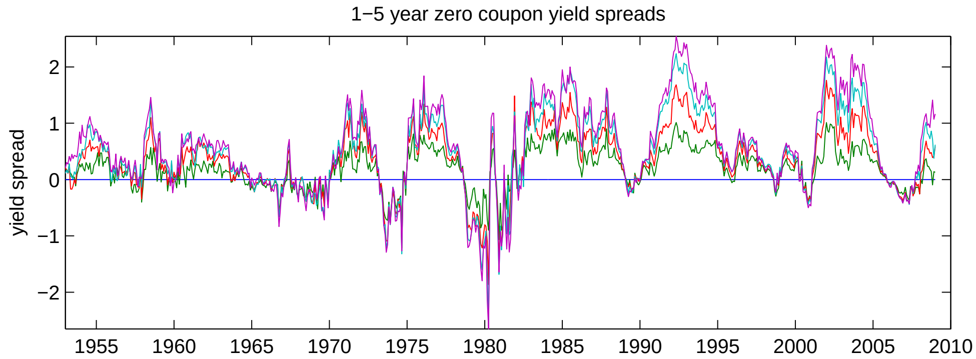
Vasicek


forwards, λ = −13.2, ρ = 0.84, 100 x σ = 1.58
forwards and expectations
yields
yields and expectations
percent
maturity
0
0.02
0.04
0.06
0.08
0.1
2
4
6
8
10

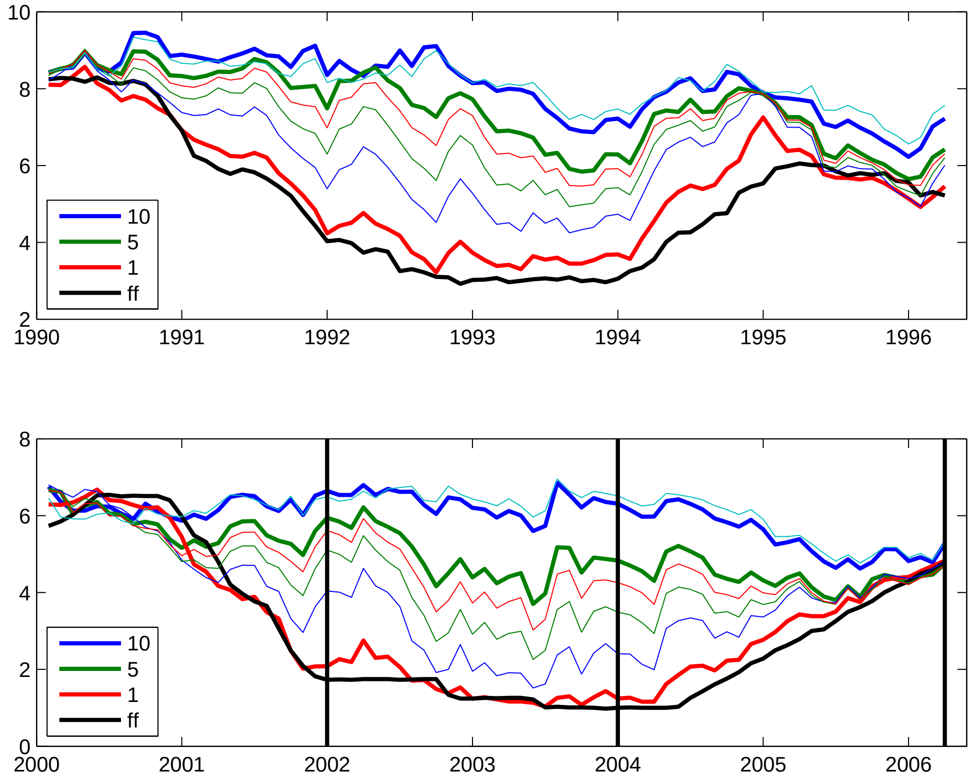

Simulation of Vasicek yield model
yields
0
5
10
15
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


1−5 year zero coupon yields
yields
0
5
10
15
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


Simulation of Vasicek yield spreads
yield spread
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

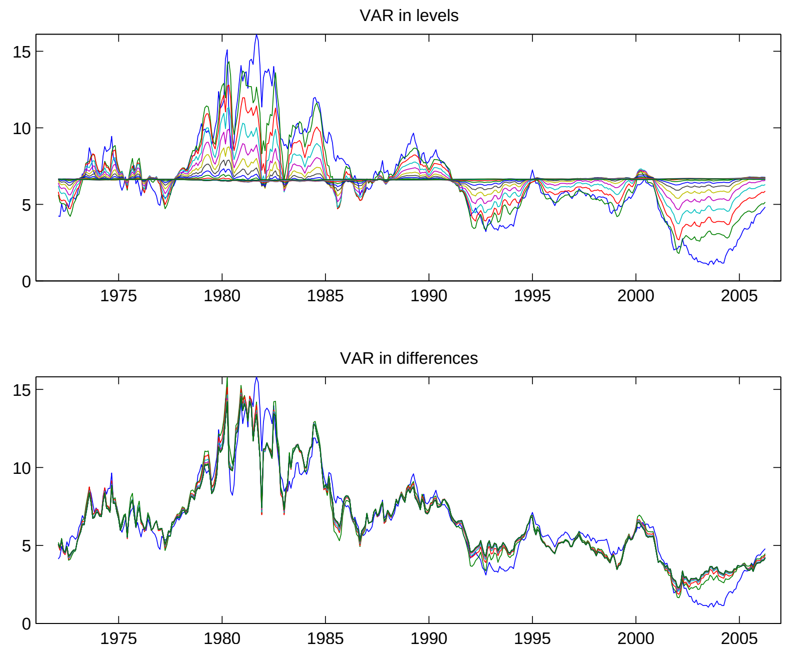

1−5 year zero coupon yield spreads
yield spread
2
1
0
−1
−2
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

CP II

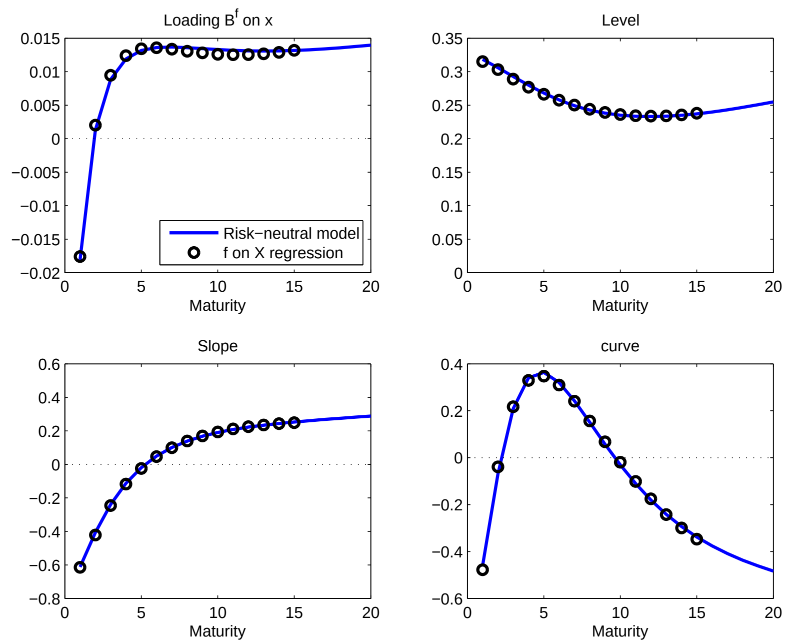


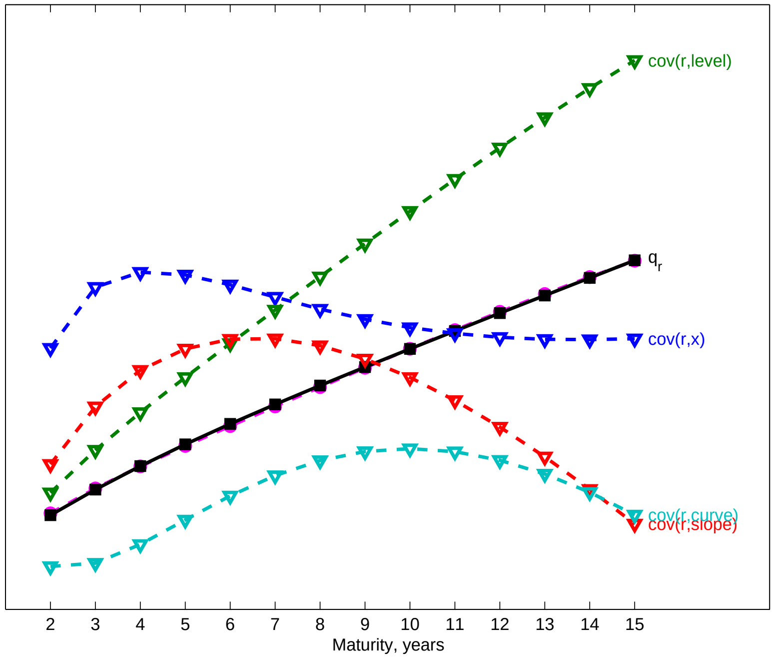
Forward rates in two recessions. The federal funds rate, 1-5, 10 and 15 year forward rates are plotted. Federal funds, 1, 5 and 10 year forwards are emphasized. The vertical lines in the lower panel highlight specific dates that we analyze more closely below.

f_t vs. $E_t r_{t+j}$?



We find ϕ^* from the cross section (nonlinear regression)



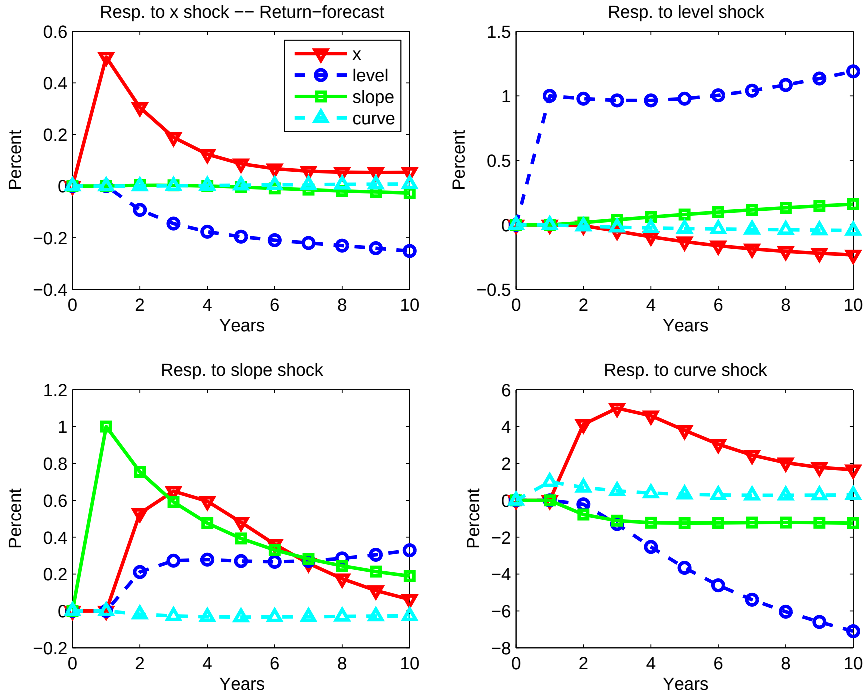


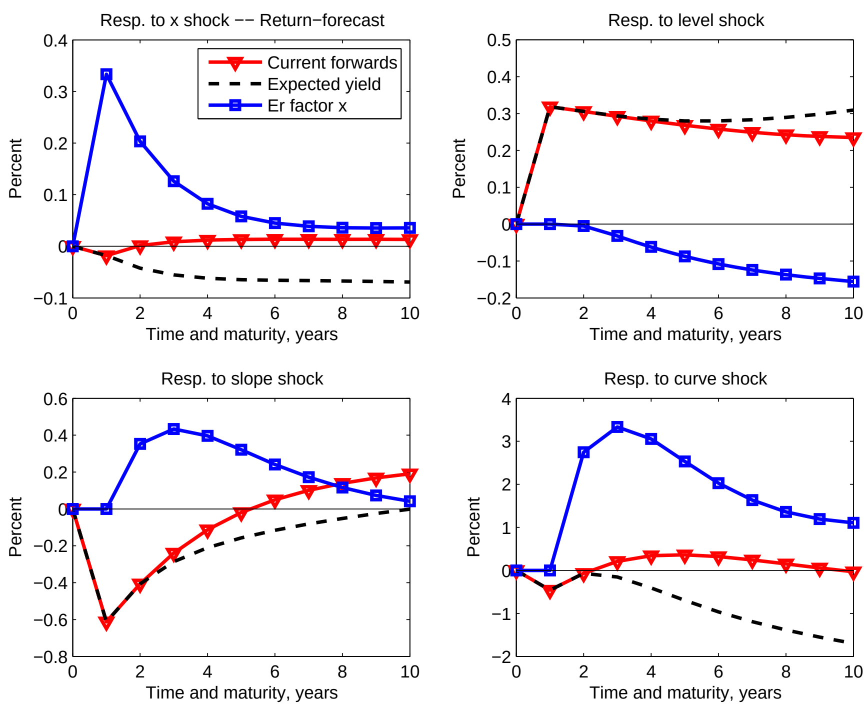
$$\lambda_t = \begin{bmatrix} 0 \\ \lambda_{0l} \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 & 0 \\ \lambda_{1l} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_t \\ level_t \\ slope_t \\ curve_t \end{bmatrix}$$

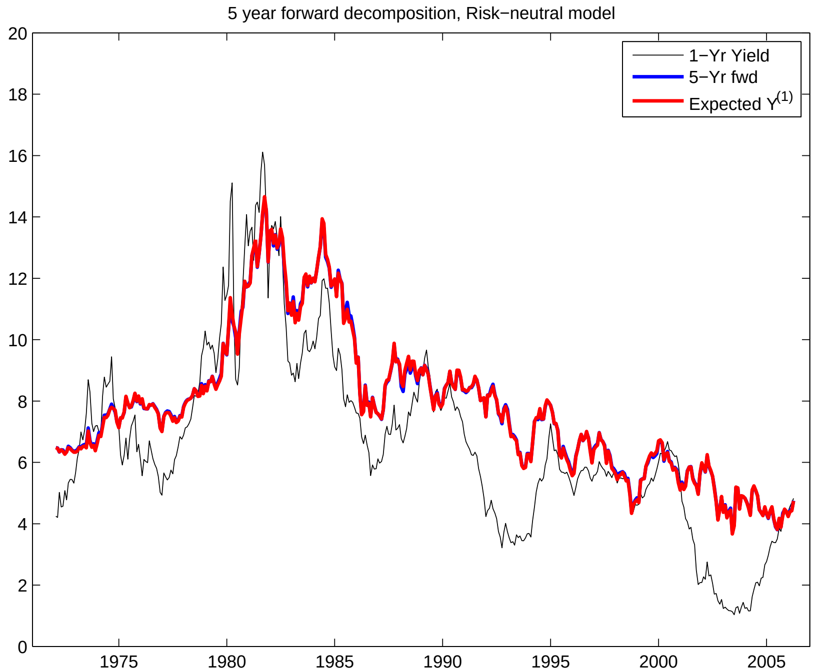
Transition Matrix Estimates

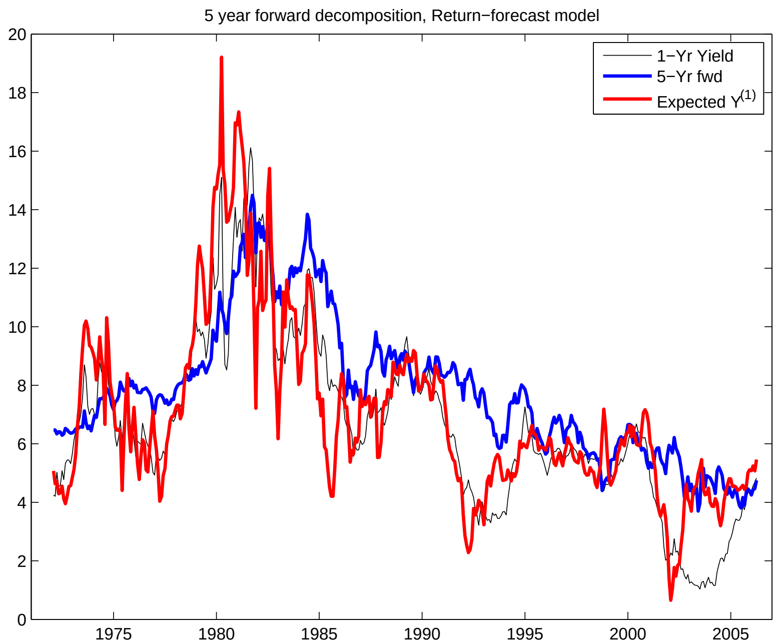
	x	level	slope	curve
Risk-neutral:		ϕ^*		
x	0.35	-0.02	-1.05	8.19
level	0.03	**0.98**	-0.21	-0.22
slope	0.00	-0.02	0.76	0.77
curve	0.00	-0.01	0.02	0.70
Actual:		ϕ		
x	*0.61*	-0.02	-1.05	8.19
level	*-0.09*	**0.98**	-0.21	-0.22
slope	*-0.00*	-0.02	0.76	0.77
curve	*0.00*	-0.01	0.02	0.70

$$rpy_t^{(n)} = \frac{1}{n}\left[E_t\left(rx_{t+1}^{(n)}\right) + E_t\left(rx_{t+2}^{(n-1)}\right) + \ldots + E_t\left(rx_{t+n-1}^{(2)}\right)\right]$$


Resp. to x shock −− Return−forecast
x
level
slope
curve
Resp. to level shock
Resp. to slope shock
Resp. to curve shock
Percent
Years


Resp. to x shock −− Return−forecast
Current forwards
Expected yield
Er factor x
Resp. to level shock
Resp. to slope shock
Resp. to curve shock
Percent
Time and maturity, years


5 year forward decomposition, Risk−neutral model
1−Yr Yield
5−Yr fwd
Expected Y(1)
0
2
4
6
8
10
12
14
16
18
20
1975
1980
1985
1990
1995
2000
2005


5 year forward decomposition, Return−forecast model
1−Yr Yield
5−Yr fwd
Expected Y(1)
0
2
4
6
8
10
12
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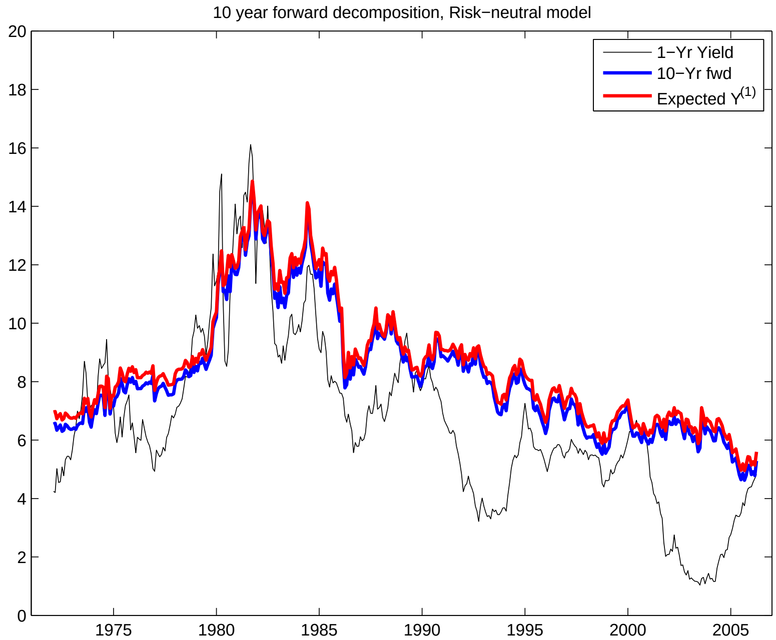
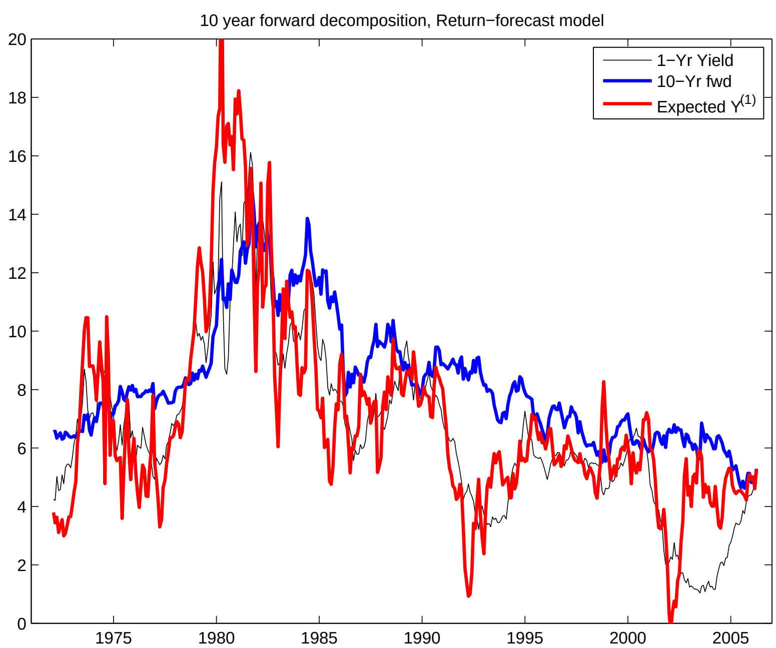
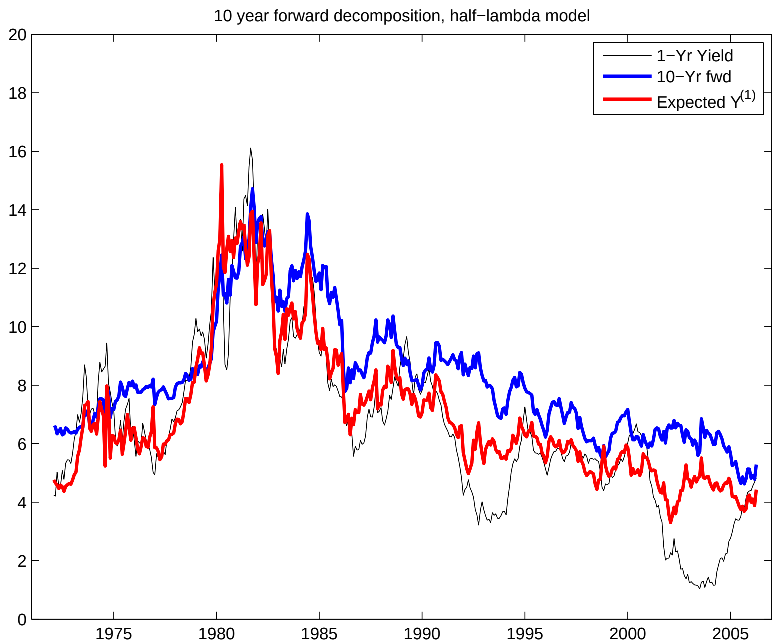
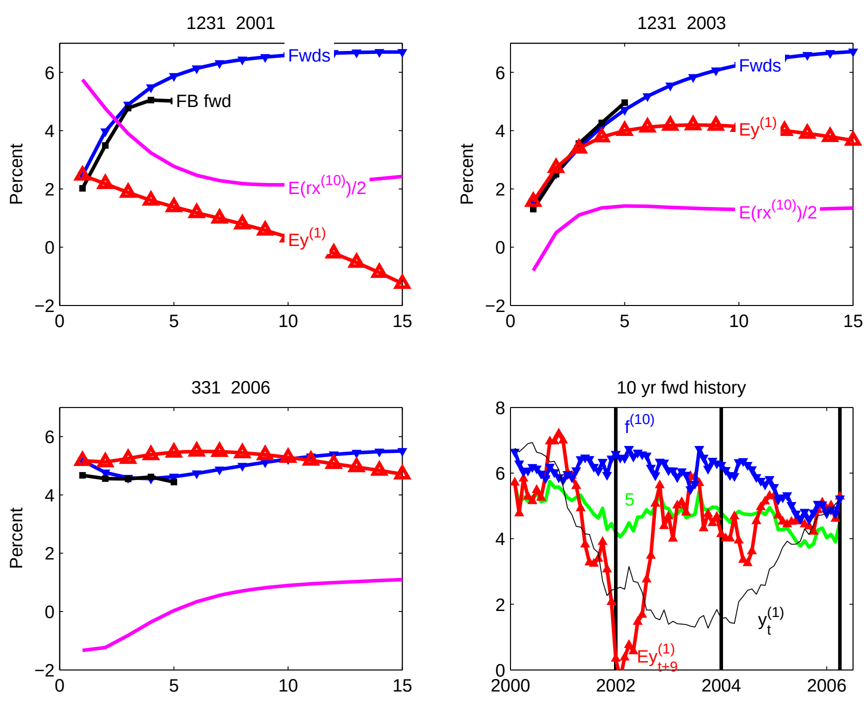
16
18
20
1975
1980
1985
1990
1995
2000
2005


10 year forward decomposition, Risk−neutral model
1−Yr Yield
10−Yr fwd
Expected Y(1)


10 year forward decomposition, Return−forecast model
1−Yr Yield
10−Yr fwd
Expected Y(1)



Data again: (Pay attention only to FB fwd vs. GSW fwds)



FX

Table 20.11.

	DM	£	¥	SF
Mean appreciation	−1.8	3.6	−5.0	−3.0
Mean interest differential	−3.9	2.1	−3.7	−5.9
b, 1975–1989	−3.1	−2.0	−2.1	−2.6
R^2	.026	.033	.034	.033
b, 1976–1996	−0.7	−1.8	−2.4	−1.3

The first row gives the average appreciation of the dollar against the indicated currency, in percent per year. The second row gives the average interest differential—foreign interest rate less domestic interest rate, measured as the forward premium—the 30-day forward rate less the spot exchange rate. The third through fifth rows give the coefficients and R^2 in a regression of exchange rate changes on the interest differential = forward premium,

$$s_{t+1} - s_t = a + b(f_t - s_t) + \varepsilon_{t+1} = a + b(r_t^f - r_t^d) + \varepsilon_{t+1},$$

where s = log spot exchange rate, f = forward rate, r^f = foreign interest rate, r^d = domestic interest rate.
Source: Hodrick (1999) and Engel (1996).

Source: *Asset Pricing*

TABLE 2

UIP Regressions, 1976-2005

	1 Month Regression			3 Month Regression		
	α	β	R^2	α	β	R^2
Belgium†	-0.002	-1.531	0.028	-0.005	-0.625	0.008
	(0.002)	(0.714)		(0.006)	(0.669)	
Canada	-0.003	-3.487	0.045	-0.007	-2.936	0.072
	(0.002)	(0.803)		(0.005)	(0.858)	
France†	0.000	-0.468	0.004	0.001	-0.061	0.000
	(0.002)	(0.589)		(0.005)	(0.504)	
Germany†	-0.005	-0.732	0.005	-0.012	-0.593	0.007
	(0.003)	(0.704)		(0.008)	(0.650)	
Italy†	0.005	-0.660	0.010	0.008	-0.012	0.000
	(0.002)	(0.415)		(0.006)	(0.392)	
Japan*	-0.019	-3.822	0.030	-0.063	-4.482	0.100
	(0.005)	(0.924)		(0.014)	(1.017)	
Netherlands†	-0.009	-2.187	0.029	-0.018	-1.381	0.026
	(0.004)	(1.040)		(0.009)	(0.816)	
Switzerland	-0.008	-1.211	0.012	-0.020	-1.050	0.022
	(0.003)	(0.533)		(0.008)	(0.536)	
USA	-0.003	-1.681	0.017	-0.008	-1.618	0.037
	(0.002)	(0.880)		(0.006)	(0.865)	

* Data for Japan begin 7/78
† Data for Euro legacy currencies ends 12/98
Notes: Regression of [S(t+1)/S(t)-1] on [F(t)/S(t)-1]. Standard errors in parentheses.

Source: Burnside et al.

Table I
UIP Regressions.

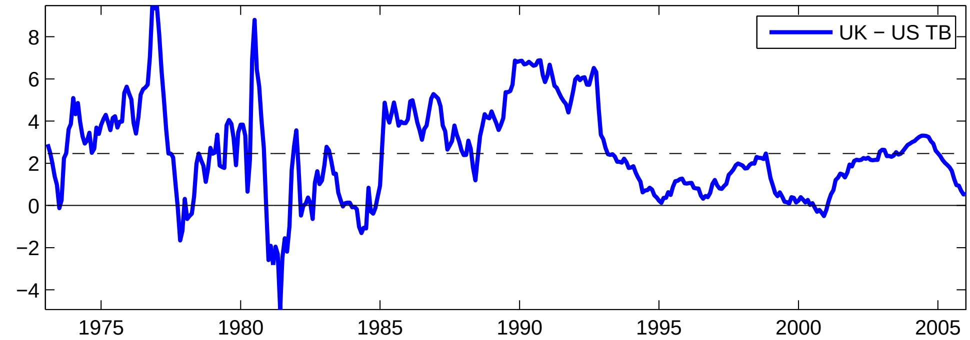
This table reports coefficient estimates from the regression of the time $t+1$ log currency return on the time t log forward premium,

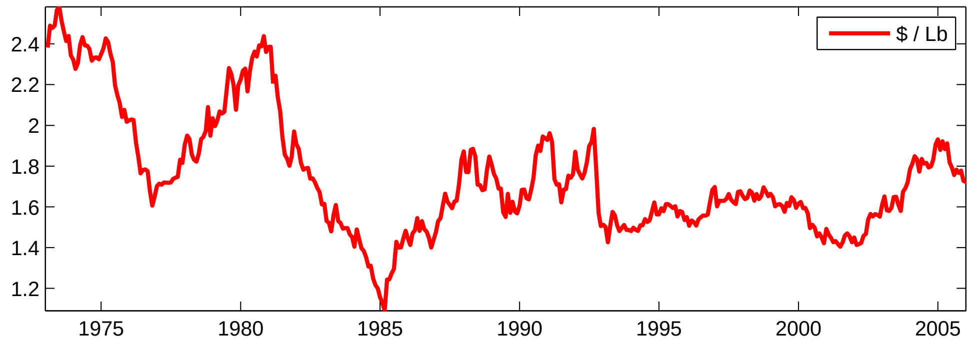
$$s_{i,t+1} - s_{i,t} = a_0 + a_1 \cdot (f_{i,t} - s_{i,t}) + \varepsilon_{i,t+1} \qquad H_0 : a_0 = 0,\, a_1 = 1$$

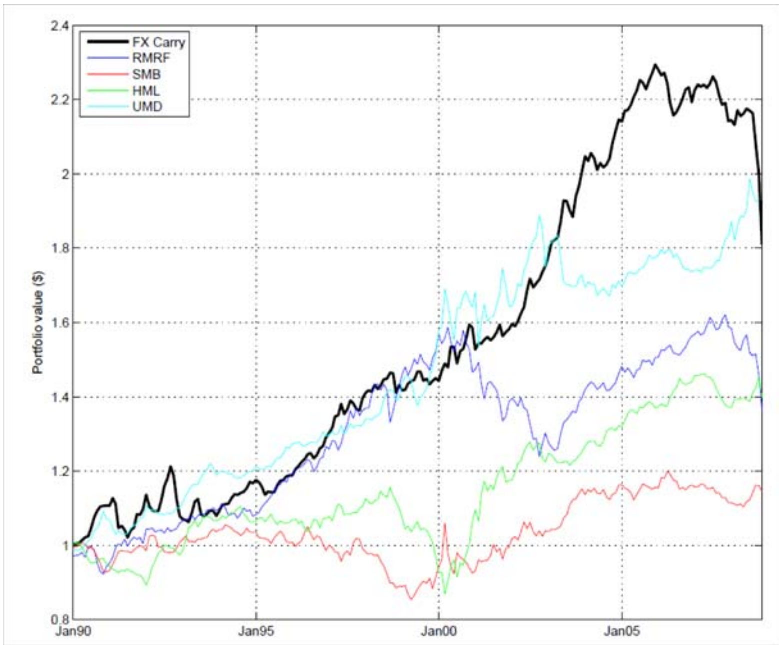
Currency returns are computed using 21-day rolling windows and span the period from January 1990 to December 2007 (all exchange rates are expressed in terms of dollars per unit of foreign currency). The forward premia are measured using the spread between one-month eurocurrency (LIBOR) rates for loans denominated in U.S. dollars and loans denominated in the foreign currency. The table reports regression coefficients, standard errors (in parentheses), and the χ^2 test statistic for the null hypothesis of UIP (p-values in parentheses). Standard errors in individual regressions are adjusted for serial correlation using a Newey-West covariance matrix with 21 lags (1990-2007: N = 4,673; 1999-2007: N = 2,542). The pooled (panel) regression is run with country-fixed effects; the reported standard errors are robust to within time-period correlation and are adjusted for serial correlation. The pooled regression χ^2 statistic is computed for the null that all country fixed effects are zero and the intercept is equal to one. R^2_{NFE} reports the adjusted R^2 from the panel regression net of the fixed effects (1990-2007: N = 42,057; 1999-2007: N = 22,878). *XS* reports the time series means and standard errors of the regression coefficients from cross-sectional regressions performed for each t. For the cross-sectional regressions R^2 is the mean adjusted R^2 (1990-2007: N = 4,673; 1999-2007: N = 2,324).

	1990-2007				**1999-2007**			
Currency	$\hat{a}_0$	$\hat{a}_1$	R^2_{NFE}	χ^2 test	$\hat{a}_0$	$\hat{a}_1$	R^2_{NFE}	χ^2 test
AUD	-0.0021	-1.6651	0.0087	9.05	-0.0021	-3.6789	0.0240	9.40
	(0.0023)	(1.0487)		(0.01)	(0.0036)	(1.9450)		(0.01)
CAD	0.0006	-0.1754	0.0000	6.87	0.0038	-1.1337	0.0016	5.93
	(0.0010)	(0.5356)		(0.03)	(0.0016)	(2.1465)		(0.05)
CHF	0.0027	-1.2094	0.0060	5.20	0.0100	-4.3559	0.0312	8.64
	(0.0024)	(0.9961)		(0.07)	(0.0041)	(1.8256)		(0.01)
GBP	0.0006	0.0591	-0.0002	1.28	0.0042	-4.3155	0.0401	11.04
	(0.0016)	(0.8981)		(0.53)	(0.0023)	(1.6417)		(0.00)
EUR	0.0021	0.7291	0.0021	3.88	0.0002	-1.6417	0.0053	4.60
	(0.0018)	(1.2675)		(0.14)	(0.0023)	(1.7499)		(0.10)
JPY	0.0059	-1.9686	0.0146	11.83	0.0048	-1.5828	0.0070	5.18
	(0.0025)	(0.8638)		(0.00)	(0.0045)	(1.3785)		(0.08)
NOK	0.0018	0.7030	0.0052	1.88	0.0017	-1.0765	0.0049	5.42
	(0.0017)	(0.6196)		(0.39)	(0.0025)	(1.2000)		(0.07)
NZD	-0.0045	-2.4182	0.0131	15.58	-0.0067	-4.7480	0.0406	16.88
	(0.0034)	(1.1961)		(0.00)	(0.0045)	(1.6800)		(0.00)
SEK	0.0006	0.6554	0.0053	0.53	0.0031	-3.2701	0.0327	10.35
	(0.0017)	(0.5966)		(0.77)	(0.0023)	(1.3594)		(0.01)
Pooled	FE	-0.0986	0.0000	7.1022	FE	-2.7863	0.0190	35.41
		(0.6500)		(0.72)		(1.1179)		(0.00)
XS	0.0007	-0.1622	0.1161	-	0.0017	-0.5154	0.1157	-
	(0.0003)	(0.0853)			(0.0005)	(0.1087)		-

Source: Jurek.


UK − US TB
8
6
4
2
0
−2
−4
1975
1980
1985
1990
1995
2000
2005


$ / Lb
2.4
2.2
2
1.8
1.6
1.4
1.2
1975
1980
1985
1990
1995
2000
2005


FX Carry
RMRF
SMB
HML
UMD
Portfolio value ($)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
Jan90
Jan95
Jan00
Jan05

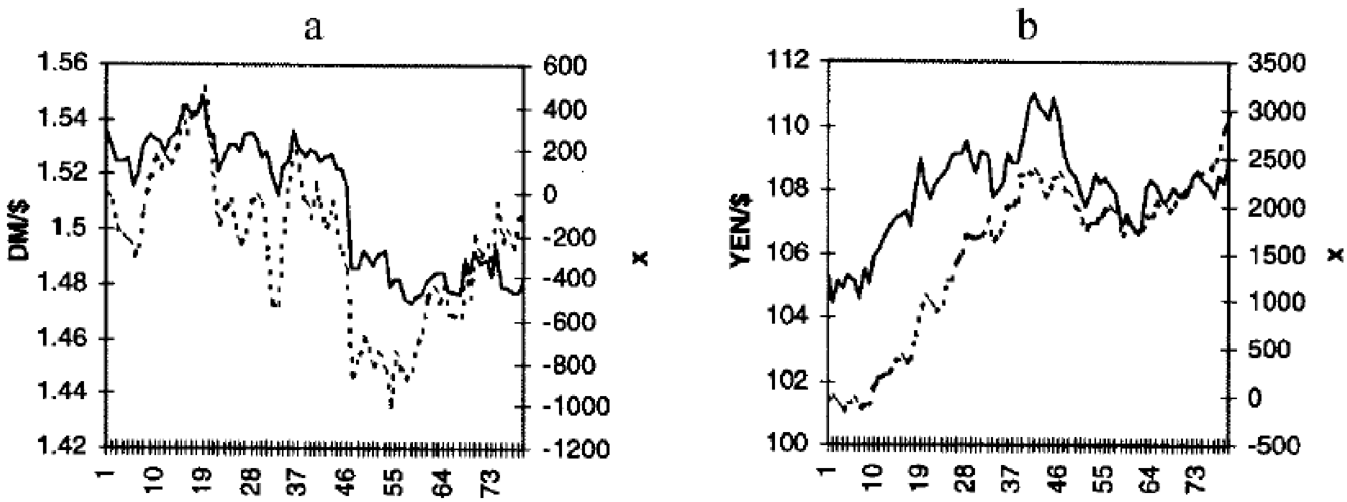


FIG. 1.—Four months of exchange rates (solid) and cumulative order flow (dashed), May 1–August 31, 1996: *a*, deutsche mark/dollar; *b*, yen/dollar.

Source: Evans and Lyons JPE

Fama-French

1. CAPM, example 1, size