Noise as Information for Illiquidity

Xing Hu
University of Hong Kong

Jun Pan
MIT

Jiang Wang
MIT

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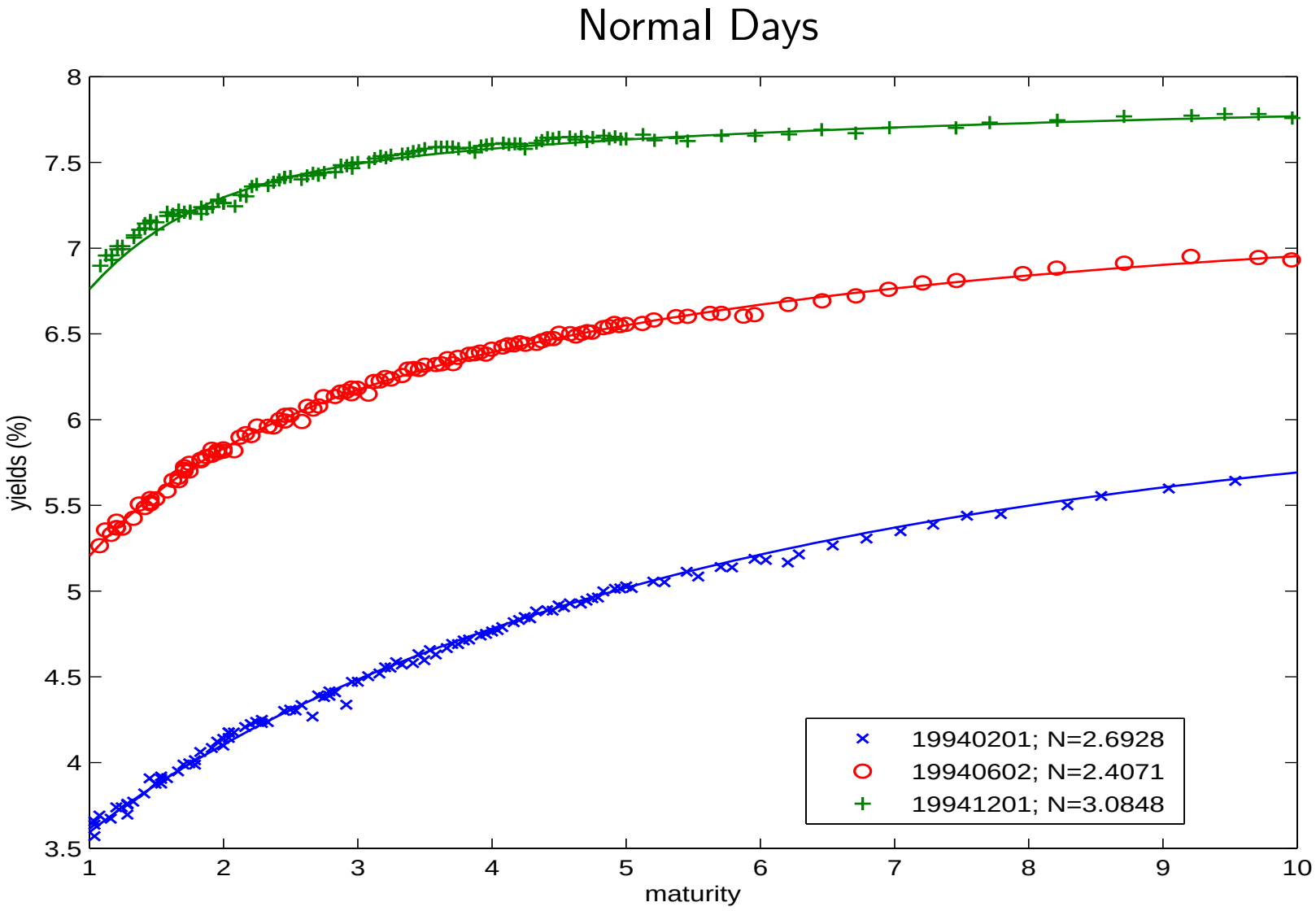
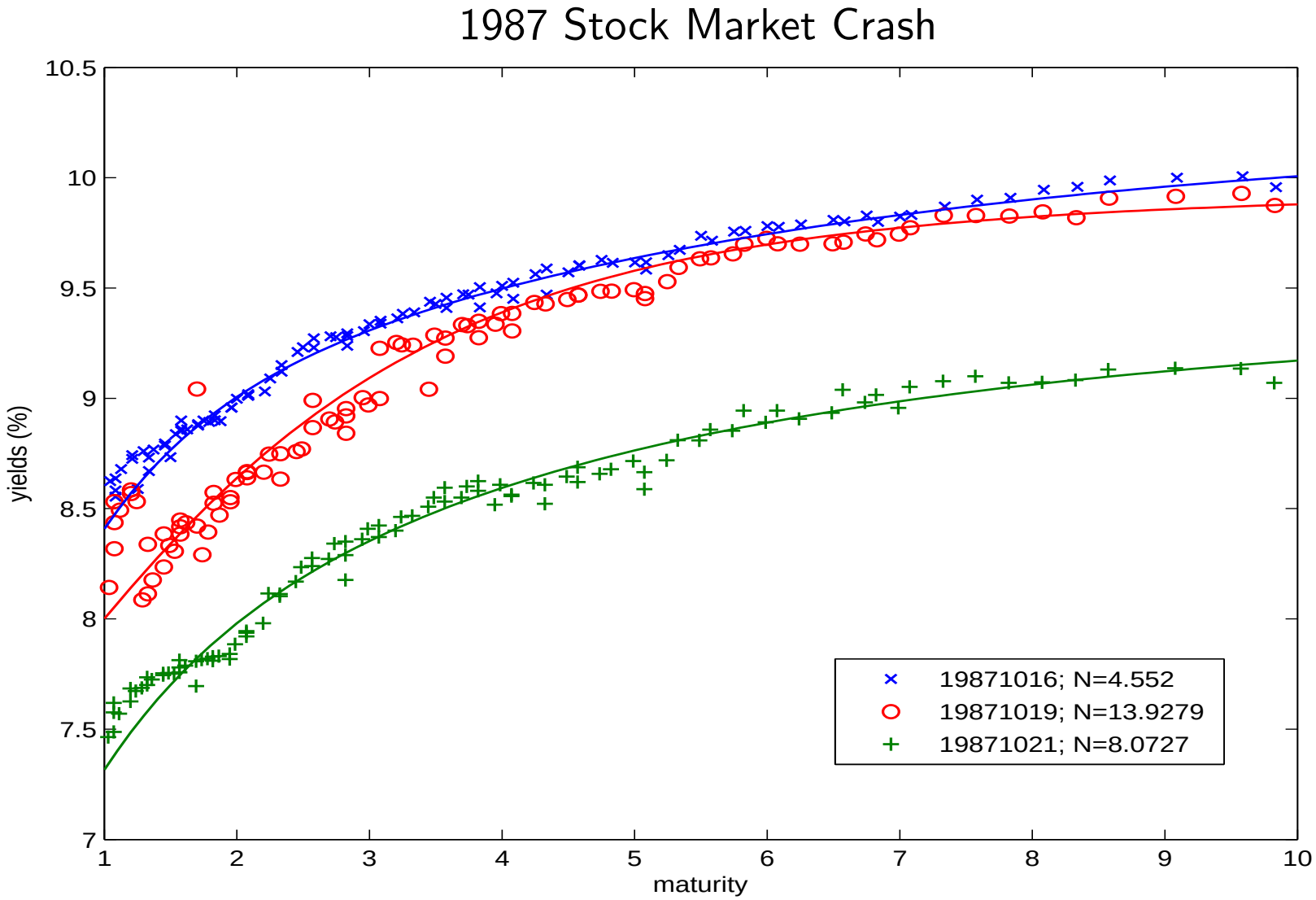
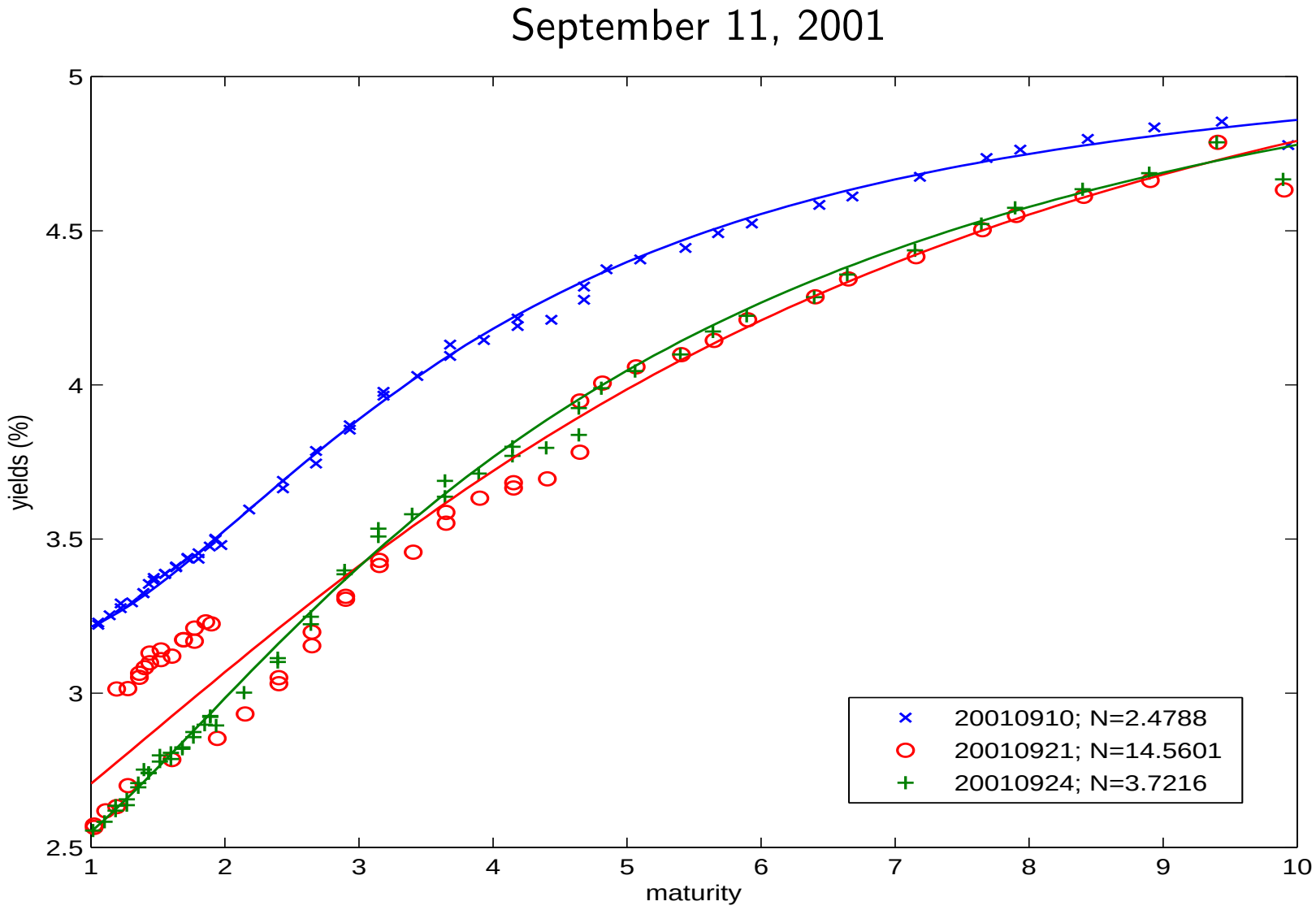
Introduction

Liquidity is essential for markets, but only partially understood:

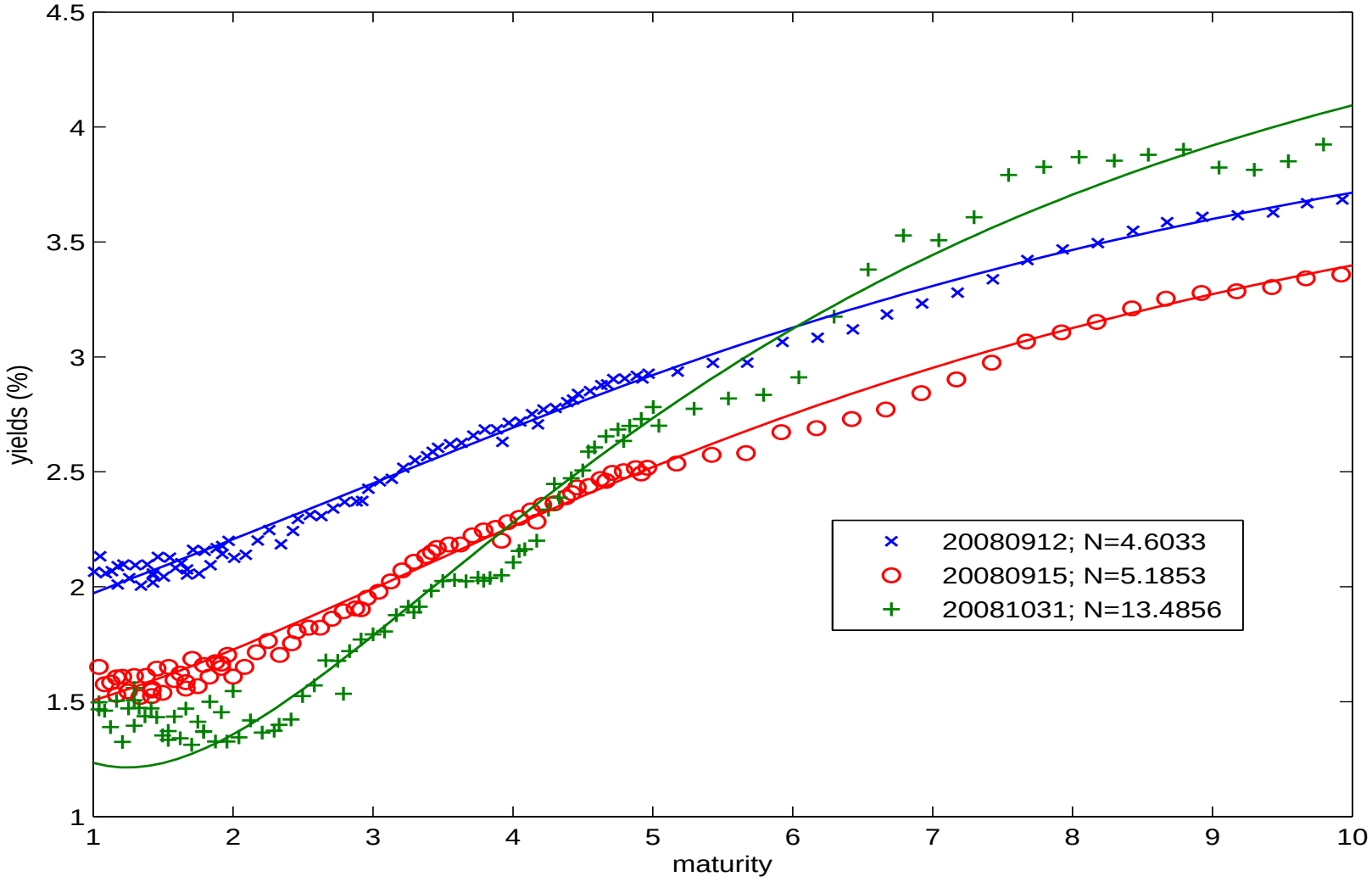
- How to measure liquidity?
  - Bid-ask spread, market depth, price impact, price reversal, ...
- What determines liquidity?
  - Frictions: trading costs, limited capital, information asymmetry, ...
- Commonality in liquidity across markets?
  - Liquidity in different markets dries up at the same time (crisis).
- How does liquidity affect asset prices?
  - Is liquidity risk a priced factor – helping to explain asset returns?


Normal Days
yields (%)
maturity
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
1
2
3
4
5
6
7
8
9
10
19940201; N=2.6928
19940602; N=2.4071
19941201; N=3.0848


1987 Stock Market Crash
yields (%)
maturity
10.5
10
9.5
9
8.5
8
7.5
7
1
2
3
4
5
6
7
8
9
10
19871016; N=4.552
19871019; N=13.9279
19871021; N=8.0727


September 11, 2001
yields (%)
maturity
5
4.5
4
3.5
3
2.5
1
2
3
4
5
6
7
8
9
10
20010910; N=2.4788
20010921; N=14.5601
20010924; N=3.7216

Lehman Collapse



"Noise" in asset prices (pricing errors) reflects market illiquidity:

- During normal times, abundance of arbitrage capital forces prices close to fundamentals.
  - Abundant arbitrage capital smooths out yields around the yield curve.
- During crisis, shortage of arbitrage capital allows prices deviate from fundamentals.
  - Limited arbitrage capital allows more "noise" in yields.
- The amount of noise in yields provides a measure of illiquidity.

Why Treasuries?

- Important: Benchmark, safe haven, ...
- Broad: Investors of many types participate.
- Pure: Mostly free of credit risk and enjoys a high level of liquidity.
- Simple: The fundamental values of Treasuries are determined by a small number of factors that can be easily captured empirically.
- Other measures of liquidity:
  - Cost of trading measures such as bid/ask spreads and price impact are narrowly focused on the markets of concern.
  - Measures from the credit, equity, and index options markets are informative, but "contaminated" with other risk factors.

Noise and Illiquidity

Data

- CRSP Daily Treasury Database
- 1987 – 2009
- Bills, notes, bonds (noncallable, no flower and no special tax treatment)
- Maturity between 1 to 10 years for noise measure

CRSP Treasury Data Summary Statistics

Sample Period	# bonds (1M-10Y)	# bonds (1Y-10Y)	Coupon (%)	Size ($B)	Bid/Ask (bps)	Maturity (year)	Age (year)	Duration (year)	Price ($)	Yield (%)
						mean				
1987-1990	157	102	9.38	8.39	3.84	3.74	2.58	3.03	103.09	8.05
1991-1995	169	112	7.44	11.18	2.54	3.64	2.64	3.09	104.13	5.83
1996-2000	155	95	6.33	13.94	2.05	3.42	2.80	2.97	101.43	5.72
2001-2005	107	64	4.57	20.99	1.25	3.75	2.74	3.34	102.86	3.51
2006-2009	149	98	3.96	22.46	1.33	3.76	2.29	3.41	103.39	2.79
All	145	92	6.33	15.32	2.17	3.65	2.65	3.16	102.93	5.19
						median				
1987-1990			8.96	7.80	3.56	3.14	2.00	2.72	101.70	8.05
1991-1995			7.47	10.20	2.11	3.21	2.09	2.87	103.88	5.85
1996-2000			6.21	13.41	1.79	2.73	2.32	2.51	100.94	5.72
2001-2005			4.57	21.12	1.00	3.07	2.00	2.87	102.07	3.44
2006-2009			4.18	20.86	1.09	3.16	1.79	2.96	103.67	2.70
All			6.27	14.71	1.87	3.05	2.06	2.78	102.36	5.16
						standard deviation				
1987-1990			2.14	3.27	1.67	2.29	2.17	1.55	6.08	0.24
1991-1995			1.51	5.09	1.35	2.13	2.20	1.55	4.24	0.53
1996-2000			0.98	7.32	1.08	2.23	2.25	1.69	2.86	0.14
2001-2005			1.29	8.23	0.75	2.45	2.53	1.96	3.77	0.52
2006-2009			0.93	6.87	0.80	2.33	2.02	1.92	3.00	0.49
All			1.37	6.31	1.12	2.29	2.27	1.74	3.98	0.39

Yield Curve Fitting and Price Noise

Svensson model for forward rates:

$$f(m,b) = \beta_0 + \beta_1 \exp\left(-\frac{m}{\tau_1}\right) + \beta_2 \frac{m}{\tau_1} \exp\left(-\frac{m}{\tau_1}\right) + \beta_3 \frac{m}{\tau_2} \exp\left(-\frac{m}{\tau_2}\right),$$

where

- m denotes time to maturity
- $b = (\beta_1\, \beta_2\, \beta_3\, \tau_1\, \tau_2)$ denotes model parameters.

The parameterized forward curve gives the zero-coupon yield curve:

$$s(m,b) = \frac{1}{m}\int_0^m f(m,b)\, dm\,.$$

For each date t, use observed bond prices P_t^i $(i = 1, \ldots, N_t)$ to estimate b:

$$b_t = \underset{b}{\text{argmax}} \sum_{i=1}^{N_t} \left[P^i(b) - P_t^i\right]^2,$$

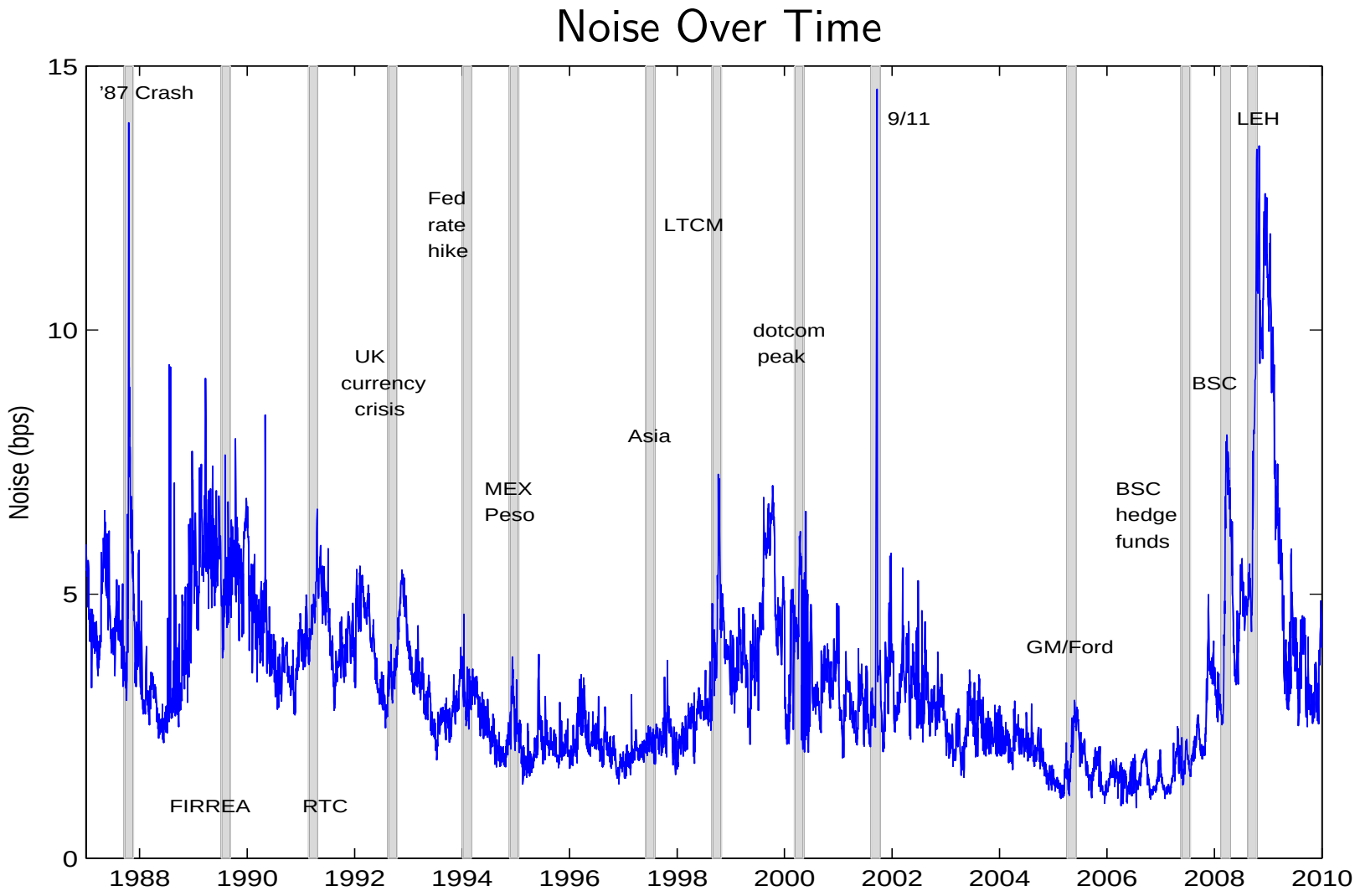
where $P^i(b)$ is the model-implied price for bond i for model parameter b.

Noise Measure

The noise measure is simply given by

$$\text{Noise}_t = \sqrt{\frac{1}{N_t}\sum_{i=1}^{N_t}\left[y_t^i - y^i(b_t)\right]^2}$$

- The noise typically treated as fitting errors.
- Why? – Prices are prices.
- Is is telling us something useful?


Noise Over Time
Noise (bps)
15
10
5
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
'87 Crash
FIRREA
RTC
UK
currency
crisis
Fed
rate
hike
MEX
Peso
Asia
LTCM
dotcom
peak
9/11
GM/Ford
BSC
hedge
funds
BSC
LEH

Time Series Properties

How our noise measure relates to other market and liquidity variables:

- Yield curve variables: level, slope and volatility
- On-the-run premium and RefCo premium
- Repo (overnight), LIBOR (3M - 3M T bill) and default spread (Baa-Aaa)
- Stock market return, VIX and liquidity (Pastor-Stambaugh)

Treasury: Level, Slope and Volatility

	(1)	(2)	(3)	(4)
△TB3M	-0.678			-0.323
	[-2.21]			[-1.25]
△Term		0.008		0.005
		[1.79]		[0.92]
△BondV			0.122	0.097
			[2.42]	[2.01]
Adj R2 (%)	3.15	3.13	4.31	6.28
# month	275	275	275	275

On-the-Run Premiums and RefCorp				
	(1)	(2)	(3)	(4)
△On5Y	0.089			0.040
	[2.35]			[1.14]
△On10Y		0.139		0.101
		[3.83]		[2.61]
△RefCorp			0.045	0.045
			[4.81]	[5.15]
Adj R2 (%)	7.35	13.74	13.56	24.89
# month	275	275	224	224

Standard Deviation Moves Away from Mean

Date	Noise	On5Y	On10Y
1987.10.19	6.45	2.00	-0.93
2001.09.21	6.83	1.15	2.63
2008.10.15	6.14	-0.37	3.98
2008.10.31	6.18	-1.78	2.50

Repo, LIBOR and Default

	(1)	(2)	(3)	(4)
△Repo	-0.461			-0.346
	[-2.43]			[-2.33]
△LIBOR		0.008		0.005
		[4.41]		[3.20]
△Default			0.018	0.019
			[2.25]	[2.24]
Adj R2 (%)	4.19	4.70	5.33	13.06
# month	223	275	275	223

Stock Market: Ret, VIX, and Liquidity

	(1)	(2)	(3)	(4)
StockRet	-0.048			0.001
	[-2.59]			[0.04]
$\triangle$VIX		0.066		0.055
		[3.89]		[3.12]
$\triangle$PSLiq			-4.99	-3.85
			[-4.28]	[-3.86]
Adj R2 (%)	5.05	11.15	11.83	18.74
# month	275	273	263	261

Liquidity Risk and Asset Returns

- Sharp rise of the noise measure during crisis of different origins and causes suggests that it may capture market-wide liquidity risk.
- Want to examine its asset pricing implications.
- In particular, can noise as a liquidity risk factor help to explain asset returns?
- Want to have test assets with returns sensitive to market-wide liquidity risk.
- Consider two sets of assets/returns:
  - Hedge fund returns,
  - Currency carry trade returns.

Liquidity Risk and Hedge Fund Returns

- Use TASS database of hedge funds from 1994 through 2009.
- Use hedge fund returns to estimate pre-ranking noise beta:

$$R_t^i = \beta_0 + \beta_i^N \, \Delta\text{Noise}_t + \beta_i^M \, R_t^M + \epsilon_t^i \, .$$

- Negative noise beta implies decreasing hedge fund returns during crises, when "noise" typically goes up.
- Sort hedge funds by their pre-ranking noise beta into 10 portfolios:
  - Portfolio 1: aggressive in taking liquidity risk, high liquidity exposure.
  - Portfolio 10: perhaps more conservative in taking liquidity risk.
- To account for high serial correlations in hedge fund returns, we use

$$R_t^p = \beta_0 + \beta_p^N \, \Delta\text{Noise}_t + \text{lag}\beta_p^N \, \Delta\text{Noise}_{t-1} + \beta_p^M \, R_t^M + \text{lag}\beta_p^M \, R_{t-1}^M$$

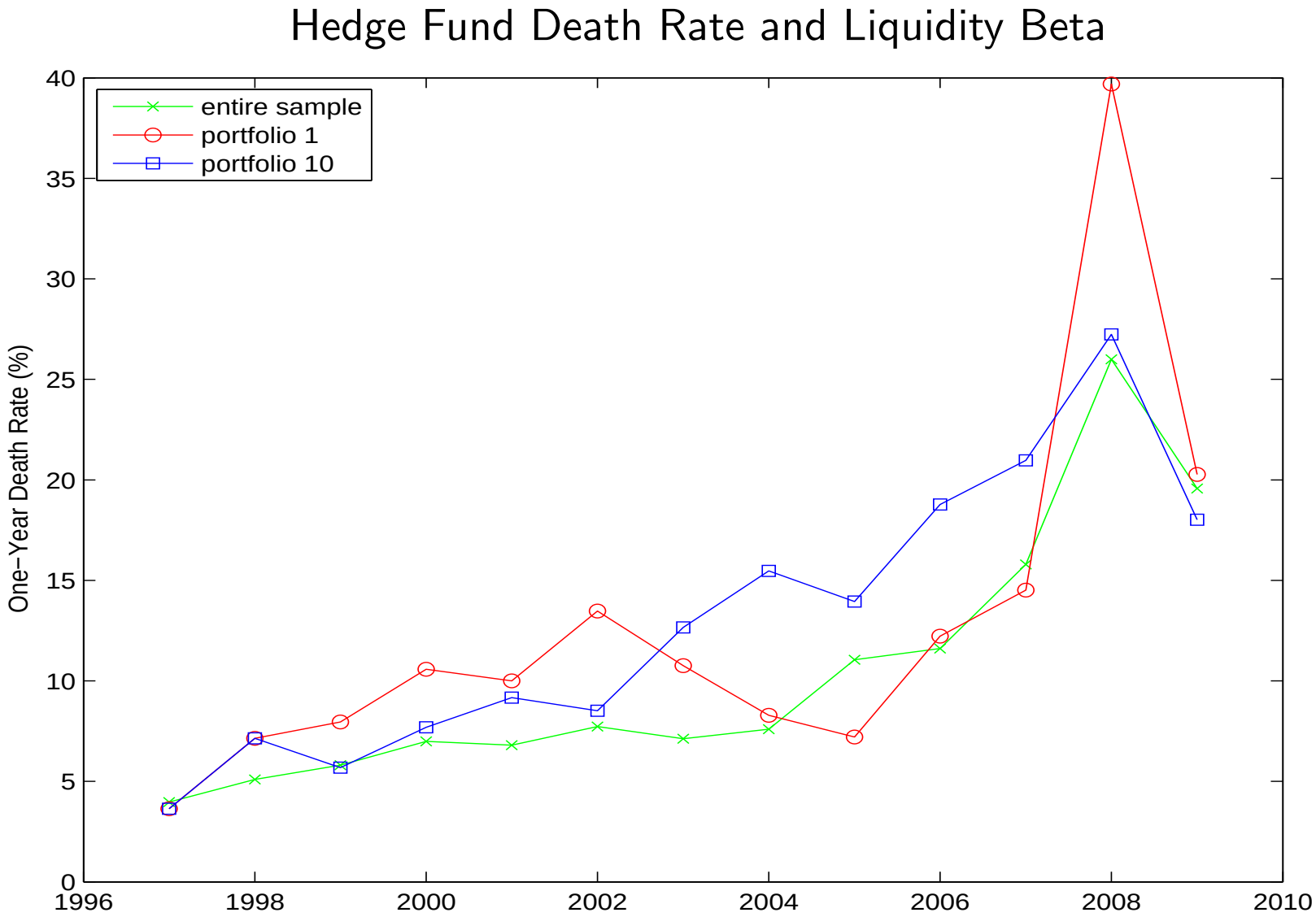
in estimating the post-ranking portfolio beta's.

Noise-Beta Sorted Portfolios

		Pre Formation		Post Formation			
	exret (%)	β^N	β^M	β^N	β^M	β^N+lag	β^M+lag
1	1.17 [4.29]	-2.55	0.50	-0.40 [-1.32]	0.45 [5.97]	-1.41 [-4.36]	0.50 [8.29]
2	0.69 [3.83]	-0.99	0.33	-0.31 [-1.62]	0.32 [6.82]	-0.87 [-3.55]	0.38 [9.07]
3	0.55 [3.90]	-0.55	0.26	-0.22 [-1.59]	0.25 [7.30]	-0.65 [-4.14]	0.30 [9.31]
4	0.45 [3.88]	-0.32	0.22	-0.22 [-1.69]	0.19 [6.61]	-0.58 [-3.82]	0.24 [9.43]
5	0.41 [3.59]	-0.16	0.20	-0.26 [-2.45]	0.20 [7.75]	-0.57 [-4.38]	0.24 [9.39]
6	0.38 [3.52]	-0.02	0.21	-0.25 [-2.38]	0.19 [7.93]	-0.50 [-3.57]	0.22 [10.0]
7	0.38 [2.98]	0.16	0.24	-0.23 [-2.06]	0.23 [7.48]	-0.39 [-2.91]	0.26 [7.52]
8	0.37 [2.70]	0.42	0.27	-0.10 [-0.87]	0.27 [8.49]	-0.16 [-1.00]	0.30 [8.13]
9	0.38 [2.40]	0.84	0.36	0.02 [0.12]	0.32 [8.39]	0.03 [0.12]	0.35 [9.06]
10	0.22 [0.88]	2.29	0.50	0.18 [0.64]	0.42 [5.68]	0.54 [1.02]	0.48 [6.45]

Noise-Beta Sorted Hedge Fund Portfolios, Characteristics

Portfolio Rank	1	2	3	4	5	6	7	8	9	10
AUM ($M)	151.44	170.62	166.80	184.45	188.59	189.40	185.61	164.48	157.29	132.59
iAUM ($M)	14.12	13.91	12.13	14.19	14.68	13.63	12.65	12.54	12.86	11.47
reporting (mn)	130	132	133	134	135	135	134	133	133	131
age (mn)	72.7	73.2	72.6	73.2	73.8	73.8	73.2	73.8	74.7	73.9
stdret (%)	3.55	2.34	1.85	1.52	1.49	1.41	1.65	1.78	2.08	3.18
auto corr	0.14	0.18	0.22	0.25	0.26	0.25	0.23	0.20	0.17	0.13
Long/Short Equity	11.88	10.64	8.38	6.09	5.55	6.18	7.94	10.97	14.63	17.73
Global Macro	17.05	13.23	7.71	7.19	5.67	6.10	6.86	10.68	12.30	13.20
Fund of Funds	4.40	7.87	11.60	14.00	14.38	14.13	13.36	10.25	6.80	3.21
Fixed Income Arb	8.93	7.70	9.90	14.74	12.04	12.03	10.83	9.39	8.13	6.31
Managed Futures	22.71	13.64	6.98	4.60	3.73	5.33	5.94	7.20	10.01	19.86
Event Driven	4.51	9.94	12.58	13.04	14.22	12.43	11.59	10.02	7.55	4.11
Equity Neutral	5.72	10.70	9.38	8.29	8.94	9.70	11.51	12.61	13.61	9.56
Emerging Markets	25.77	13.32	8.64	5.45	5.02	5.05	6.45	7.91	9.17	13.22
Convertible Arb	7.30	8.95	10.32	14.50	15.25	13.98	10.59	9.95	6.10	3.07
Others	6.87	9.79	11.17	11.06	11.76	12.18	10.05	9.63	10.20	7.28


Hedge Fund Death Rate and Liquidity Beta
entire sample
portfolio 1
portfolio 10
One−Year Death Rate (%)
0
5
10
15
20
25
30
35
40
1996
1998
2000
2002
2004
2006
2008
2010

Liquidity Risk and Currency Carry-trade Returns

- Construct six carry portfolios by sorting currencies by their interest rate differentials relative to the US:
  - Portfolio 1: low interest rates, typically used as "funding" currencies.
  - Portfolio 6: high interest rates, used as "target" or "asset" currencies.
- Estimate each portfolio's risk exposures by

$$R_t^i = \beta_0 + \beta_i^N \, \Delta\text{Noise}_t + \beta_i^M \, R_t^M + \epsilon_t^i \, .$$

- Again, negative β^N implies decreasing portfolio returns during crises, when "noise" typically goes up.

Currency Carry Portfolios (198701-200912)

	exret (%)	β^N	β^M
6 ("asset" currencies)	0.81	-0.43	0.14
	[4.47]	[-1.83]	[2.15]
5	0.34	-0.04	0.12
	[2.41]	[-0.25]	[2.64]
4	0.31	-0.07	0.07
	[2.33]	[-0.36]	[1.31]
3	0.16	0.17	0.06
	[1.25]	[1.06]	[1.32]
2	-0.06	0.07	0.04
	[-0.51]	[0.44]	[1.06]
1 ("funding" currencies)	-0.20	0.27	-0.01
	[-1.50]	[1.91]	[-0.18]

Liquidity Risk Premium

- Fama and MacBeth (1973) monthly cross-sectional regressions to estimate premium:

$$R_t^i = \gamma_{0t} + \gamma_t^N \beta_i^N + \gamma_t^M \beta_i^M + c_t^{\text{age}} \text{age}_t^i + c_t^{\text{AUM}} \text{AUM}_t^i + \varepsilon_t^i,$$

  with controls for hedge fund age and size.

- The time series average of γ_t^N is an estimate of the liquidity risk premium.

- We perform the same tests for a few other liquidity measures.

Liquidity Risk Premium: Noise Measure

Using Hedge Fund Returns	Liquidity	Market	Age	AUM
Noise	-1.43	1.76	0.0001	-0.11
	[-2.86]	[2.60]	[0.19]	[-4.18]
Noise (beta+lag beta)	-0.44	1.00	0.0002	-0.11
	[-2.81]	[1.79]	[0.25]	[-4.24]
Using Currency Carry Returns	Liquidity	Market		
Noise	-0.82	2.93		
	[-2.54]	[2.29]		

Liquidity Risk Premium: Other Proxies of Liquidity

Factor	Liquidity	Market	Age	AUM
Noise	-1.43	1.76	0.0001	-0.11
	[-2.86]	[2.60]	[0.19]	[-4.18]
On5Y	-2.21	1.00	0.0001	-0.11
	[-0.77]	[1.76]	[0.1]	[-4.49]
On10Y	0.38	2.07	0.0001	-0.11
	[0.59]	[2.25]	[-0.08]	[-4.31]
RefCorp	-4.60	0.75	0.0001	-0.12
	[-1.26]	[1.26]	[0.36]	[-4.32]
PSLiq	0.93	-0.02	0.0001	-0.11
	[0.88]	[-0.18]	[-0.57]	[-4.36]
VIX	-0.25	1.04	0.0001	-0.11
	[-0.07]	[1.42]	[-0.04]	[-4.23]

Conclusion

- A broad and pure measure of illiquidity based on the connection between:
  - Liquidity,
  - Amount of arbitrage capital available in the market,
  - Price "noise" in US Treasuries.
- Empirically, it captures various episodes of liquidity crises.
- It is related to (but not taken over by) other known measures of illiquidity.
- As a liquidity risk factor, it helps to explain returns of liquidity sensitive assets/strategies:
  - Hedge funds,
  - Currency carry trades.