Global Risk, Uncertainty and Volatility Measurement

Douglas T. Breeden*

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Reference notes for Federal Reserve Board talk in Washington, D.C., at their roundtable on "Global Risk, Uncertainty and Volatility."

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Perspectives on Global Risk, Uncertainty and Volatility

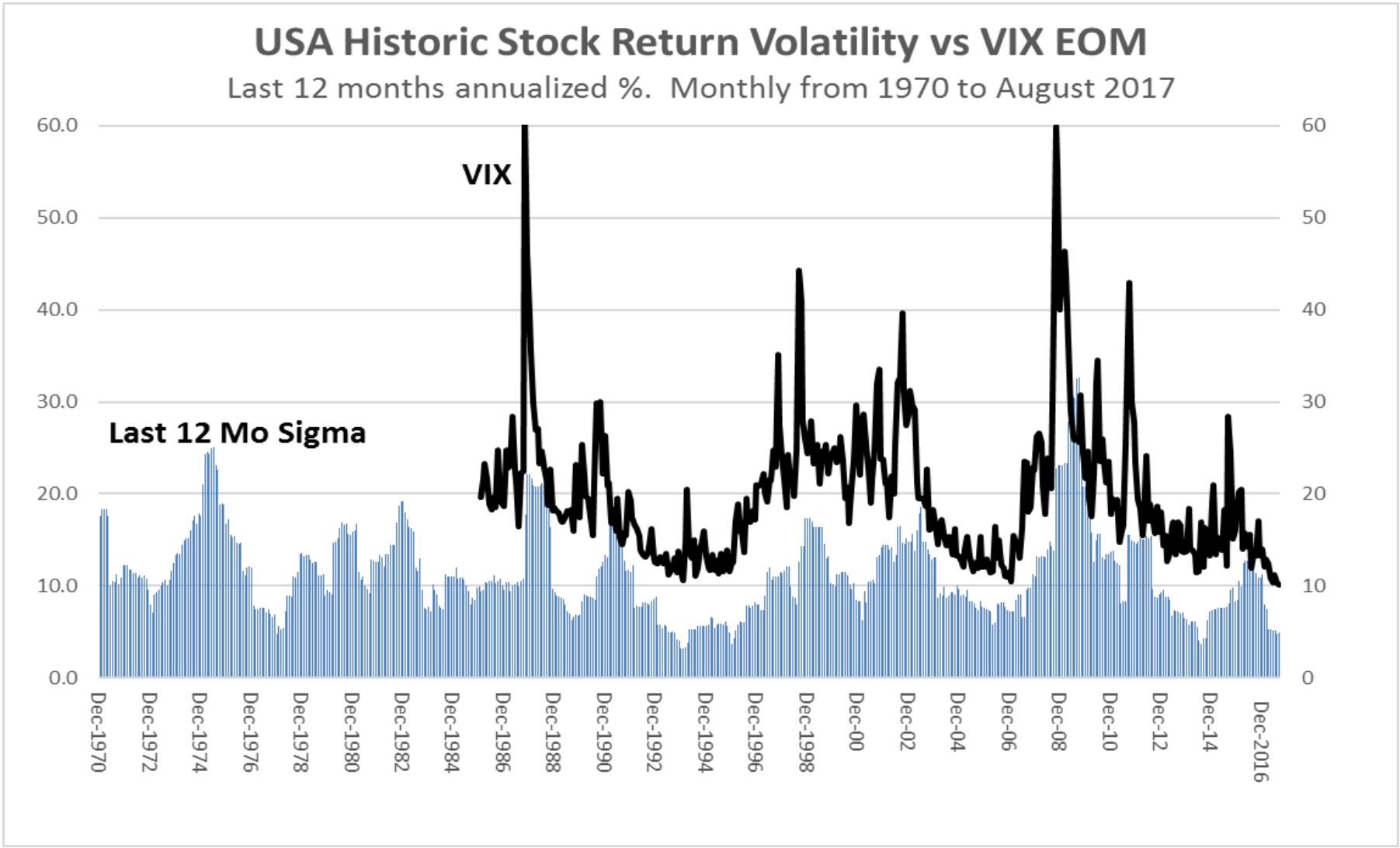
1. Volatility is like standard deviation, which picks up **total volatility** of fluctuations, weighting good deviations as much as bad ones.

2. **Uncertainty**: I think of that as like **estimation risk**, not being able to identify and estimate factors and to estimate sensitivities to them well (like durations, betas, correlations).

3. **Global risk** is the main item I examine. I take it to mean examining fluctuations such as increases in **unemployment** or drops in GDP, wealth or income that clearly **hurt a lot of people**. It is more "downside risk" or "drawdown risk," as wealth and income and employment fall from prior peak levels.

I. Volatility: Gives equal weight to positive and negative deviations.

As low as VIX is, historic volatility is even lower. Traders risk averse.



II. Uncertainty: Estimation Risk for Major Risk Parameters.

Example: Brokers Differ Hugely on Basic Duration Risk for IOs

Breeden (1994, Journal of Fixed Income, "Complexities of Hedging Mortgages"

Broker Forecasts

Interest Only Strip Option Adjusted Durations

December 31, 1991(Par Yield = 7.55)

	#1 Goldman	#2 Prudential	#3 JPMorgan	#5 BS	#6 DLJ
6.5					
7.0					
7.5					
8.0	(6.4)	(3.7)	(6.1)		
8.5	(9.5)	(8.6)	8.9		
9.0	(16.8)	(16.8)	12.1		
9.5	(22.0)	(16.9)	12.8		
10.0	(24.0)	(12.1)	12.1		
10.5		(5.7)	(9.6)		

December 31, 1994(Par Yield = 8.88)

	#1 Goldman	#3 JPMorgan	#4 Salomon	#5 BS	#6 DLJ
6.5	1.3			(1.5)	1.9
7.0	(0.4)	(1.9)		(2.7)	0.8
7.5	(1.7)	(3.8)		(4.3)	(0.8)
8.0	(2.6)	(6.1)		(6.0)	(3.1)
8.5	(2.9)	(7.7)			(2.7)
9.0	(4.2)	(8.9)		(6.7)	(6.3)
9.5	(4.9)	(10.0)		(5.6)	(9.9)
10.0	(4.5)	(11.8)		(5.8)	(15.4)
10.5		(12.9)		(8.2)	

December 31, 1992(Par Yield = 7.55)

	#1 Goldman	#2 Prudential	#3 JPMorgan	#5 BS	#6 DLJ
6.5					
7.0					
7.5					
8.0	(4.0)	(8.1)	(9.0)		
8.5	(7.4)	(12.4)	(15.0)	(7.3)	
9.0	(17.3)	(14.7)	(18.0)	(7.6)	
9.5	(22.8)	(12.5)	(17.0)	(8.8)	
10.0	(28.3)	(8.6)	(12.0)	(9.0)	
10.5		(5.9)	(8.0)	(12.4)	

December 31, 1995(Par Yield = 6.79)

	#1 Goldman	#3 JPMorgan	#4 Salomon	#5 BS	#6 DLJ
6.5	(6.1)		(17.2)	(16.1)	(5.0)
7.0	(14.9)		(28.1)	(22.0)	(12.2)
7.5	(25.0)		(40.5)	(28.9)	(21.5)
8.0	(33.9)		(37.7)	(34.5)	(40.8)
8.5	(23.4)		(22.3)	(25.1)	(61.2)
9.0	(19.4)		(17.9)	(13.7)	(12.6)
9.5	(14.5)		(15.4)	(9.0)	(10.9)
10.0	(10.7)		(13.2)	(7.4)	(11.8)
10.5			(12.6)	(8.5)	

December 31, 1993(Par Yield = 6.67)

	#1 Goldman	#2 Prudential	#3 JPMorgan	#5 BS	#6 DLJ
6.5					(13.3)
7.0	(22.4)	(17.0)	8.5		(16.5)
7.5	(34.6)	(27.8)	9.8		(26.8)
8.0	(41.6)	(32.4)	11.5		(31.3)
8.5	(11.3)	(17.4)	3.8		(26.7)
9.0	(5.8)	(14.1)	(5.1)	(12.4)	(24.2)
9.5	(5.6)	(11.0)	(5.1)	(12.5)	(24.7)
10.0	(4.1)	(6.1)	(0.6)	(12.1)	(24.5)
10.5			4.7	(14.8)	

June 30, 1996(Par Yield = 7.80)

	#1 Goldman	#3 JPMorgan	#4 Salomon	#5 BS	#6 DLJ
6.5	1.3			(1.5)	1.9
7.0	(0.4)		(1.9)	(2.7)	0.8
7.5	(1.7)		(3.8)	(4.3)	(0.8)
8.0	(2.6)		(6.1)	(6.0)	(3.1)
8.5	(2.9)		(7.7)		(2.7)
9.0	(4.2)		(8.9)	(6.7)	(6.3)
9.5	(4.9)		(10.0)	(5.6)	(9.9)
10.0	(4.5)		(11.8)	(5.8)	(15.4)
10.5			(12.9)	(8.2)	

Uncertainty: Estimation Risk. Brokers Differ Hugely on Option Costs for Mortgage Interest Only Strips (IOs). Sign even differs!

Exhibit 11a
4 Brokers: 7.0% Interest Only Option Costs
Monthly April 1991 - June 1996

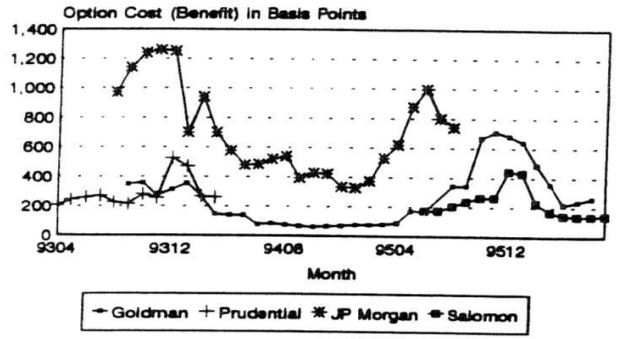


Exhibit 11b
4 Brokers: 8.0% Interest Only Option Costs
Monthly September 1991 - June 1996

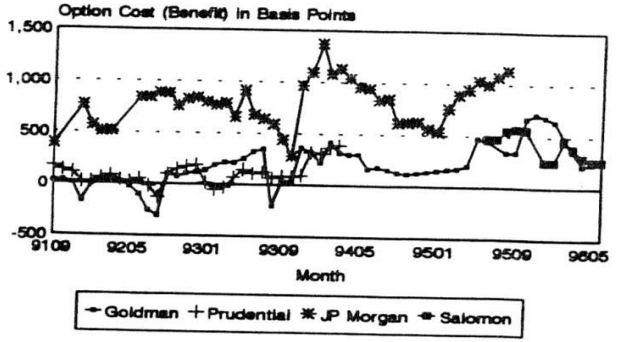


Exhibit 11c
4 Brokers: 9.0% Interest Only Option Costs
Monthly September 1991 - June 1996

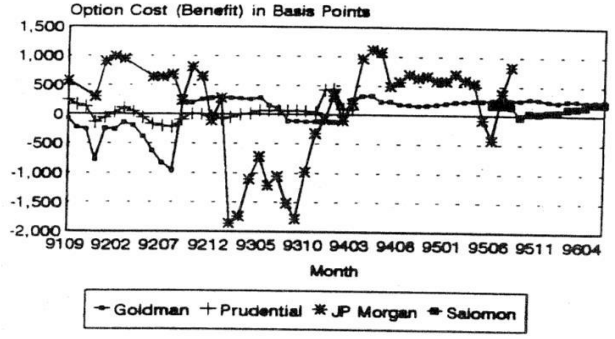
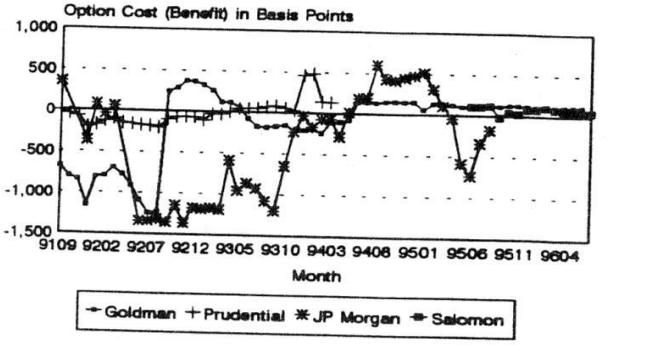


Exhibit 11d
4 Brokers: 10.0% Interest Only Option Costs
Monthly September 1991 - June 1996



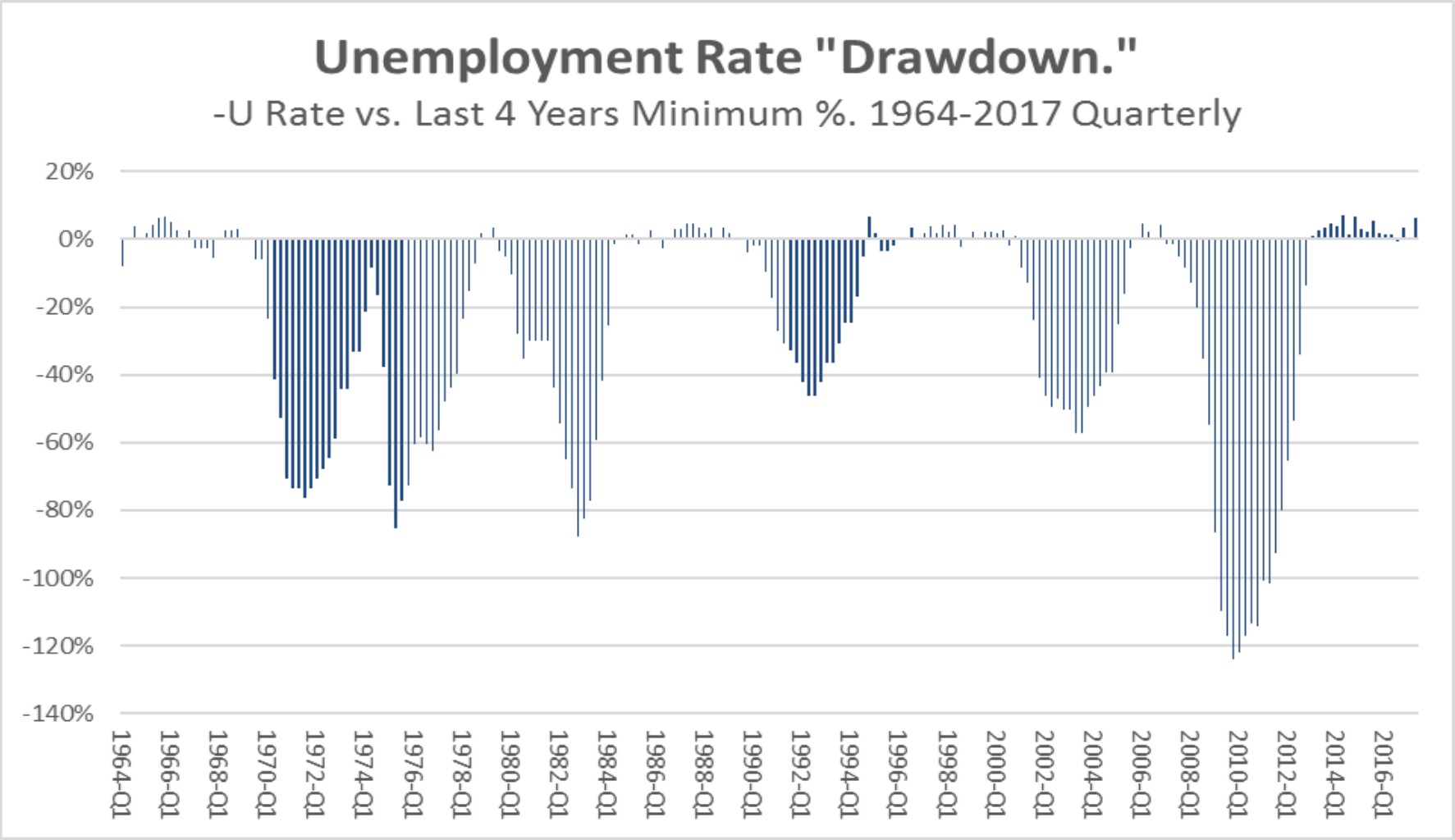
III. Measuring Global Risk: A Simple and Intuitive Model: SBCLI

"A Stocks, Bonds, Consumers Leading Indicator"

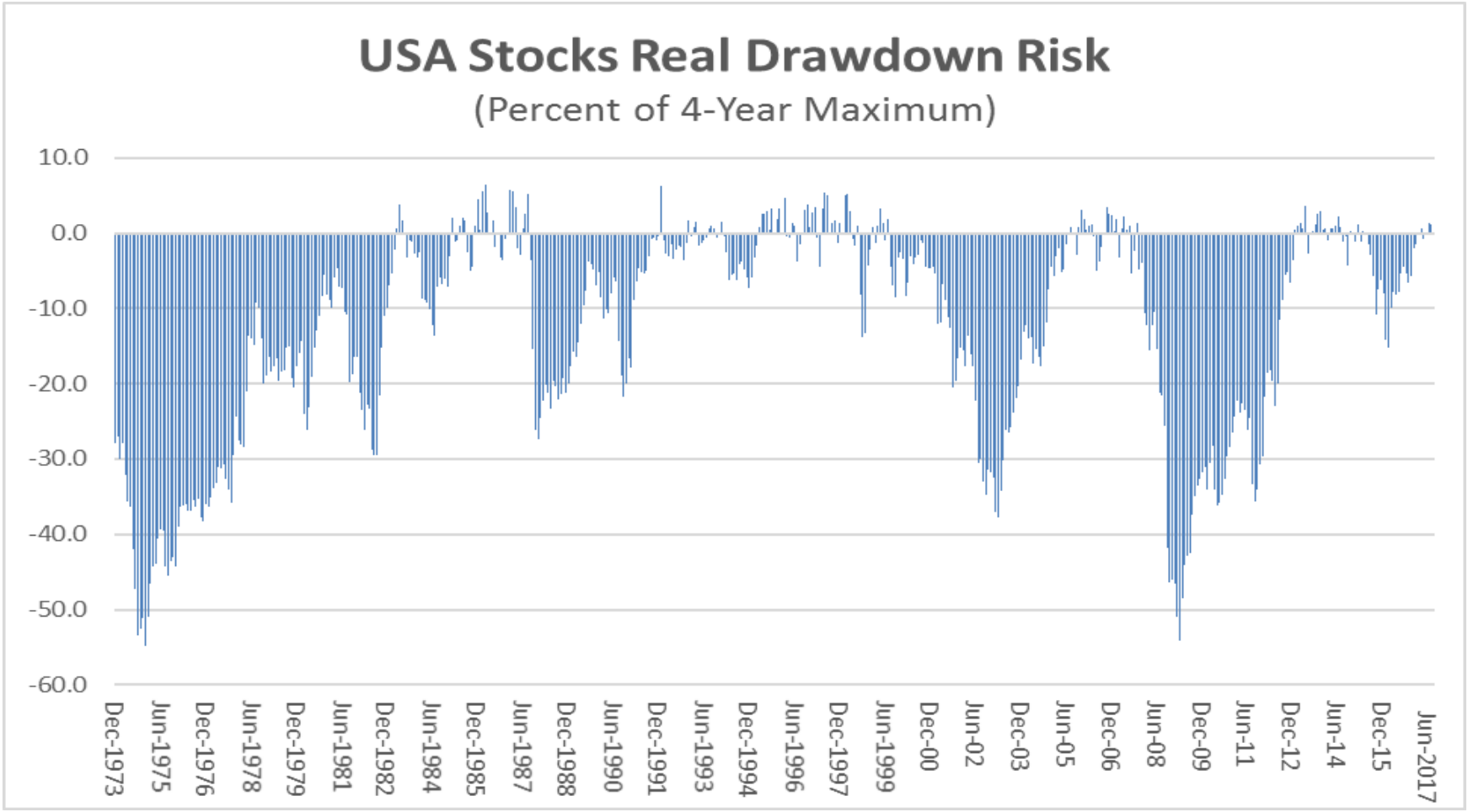
Source: Breeden (2011-2016)

Risk is used here to be downside risk, or drawdown from peak risk, where many people are hurt by the fluctuations, after they were accustomed to prior living habits.

Unemployment Drawdowns Identify the Most Serious Recessions



Stock price drops from peak (drawdowns) do not seem to Measure real economic pain as much as macro drawdowns



A Stocks, Bonds, Consumers Leading Indicator (SBCLI©) With Only Three Key, Intuitive Factors In Forecasting, We Can Do Nearly As Well As The 10 Factor LEI

S. **Stocks: Stock market prices** reflect profit forecasts, which are related to forecasted economic growth.

B. **Bonds: Term structure slope (long term rate – short term rate, e.g., 10 year rate – 3 month rate)** predicts increases and slowdowns in economic growth for advanced economies with little credit risk. For emerging economies, **sovereign bond credit spreads** over USA are used as leading indicators.

C. **Consumers:** Consumers make thoughtful, intelligent choices. **Consumption growth that is independent of stock market returns** reflects consumers' views of jobs, incomes and investment opportunities.

Source: *"A Stocks, Bonds, Consumers Leading Indicator," Breeden 2016*

Standardized Z-Scores for Real Stock Returns, Term Structure Slope, & Consumption Deviations

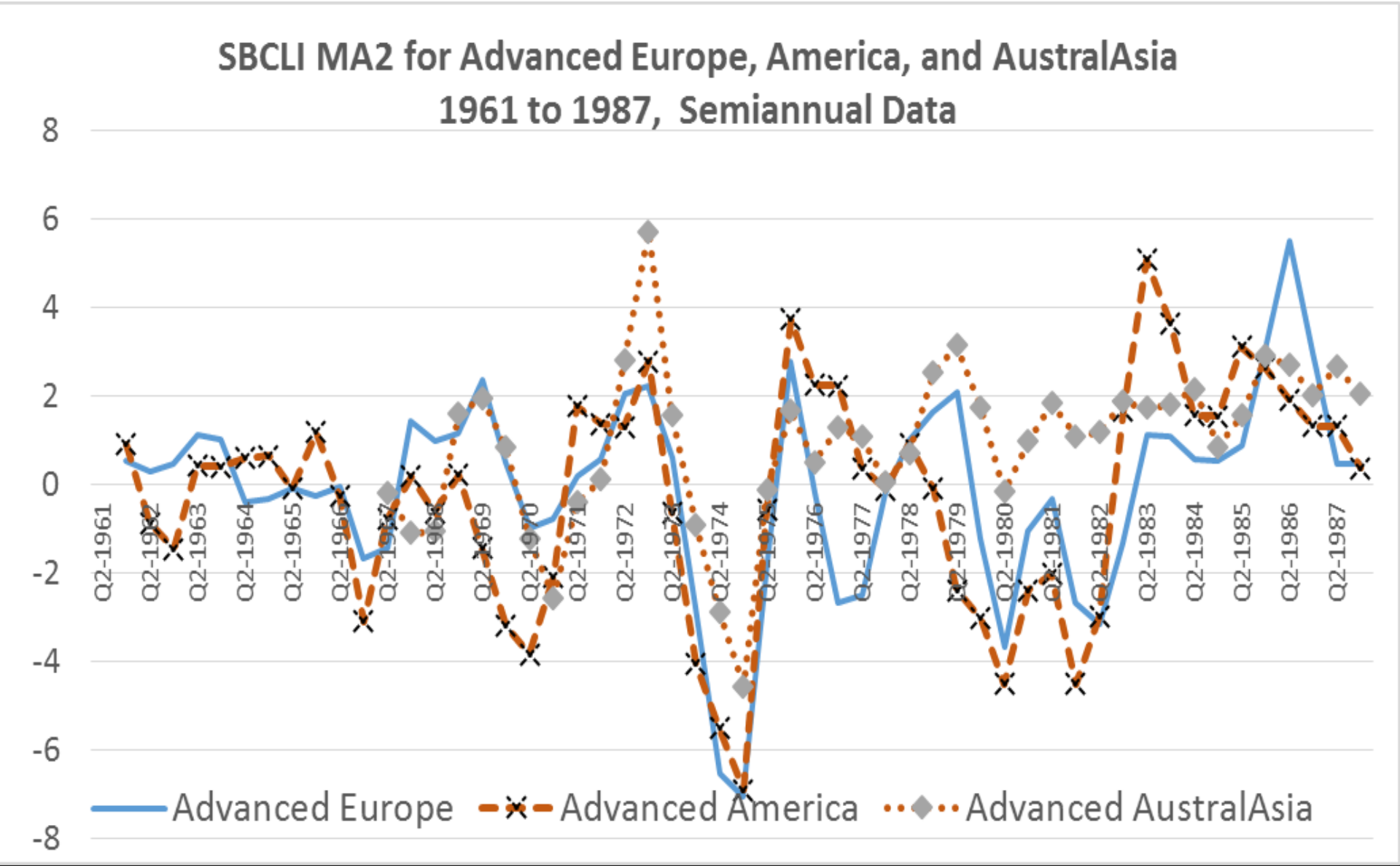
- For key variable k (k = Stocks return, bond slope, consumer deviation) at time t: $Z_{kt} = \frac{(x_{kt} - \mu_k)}{\sigma_k}$

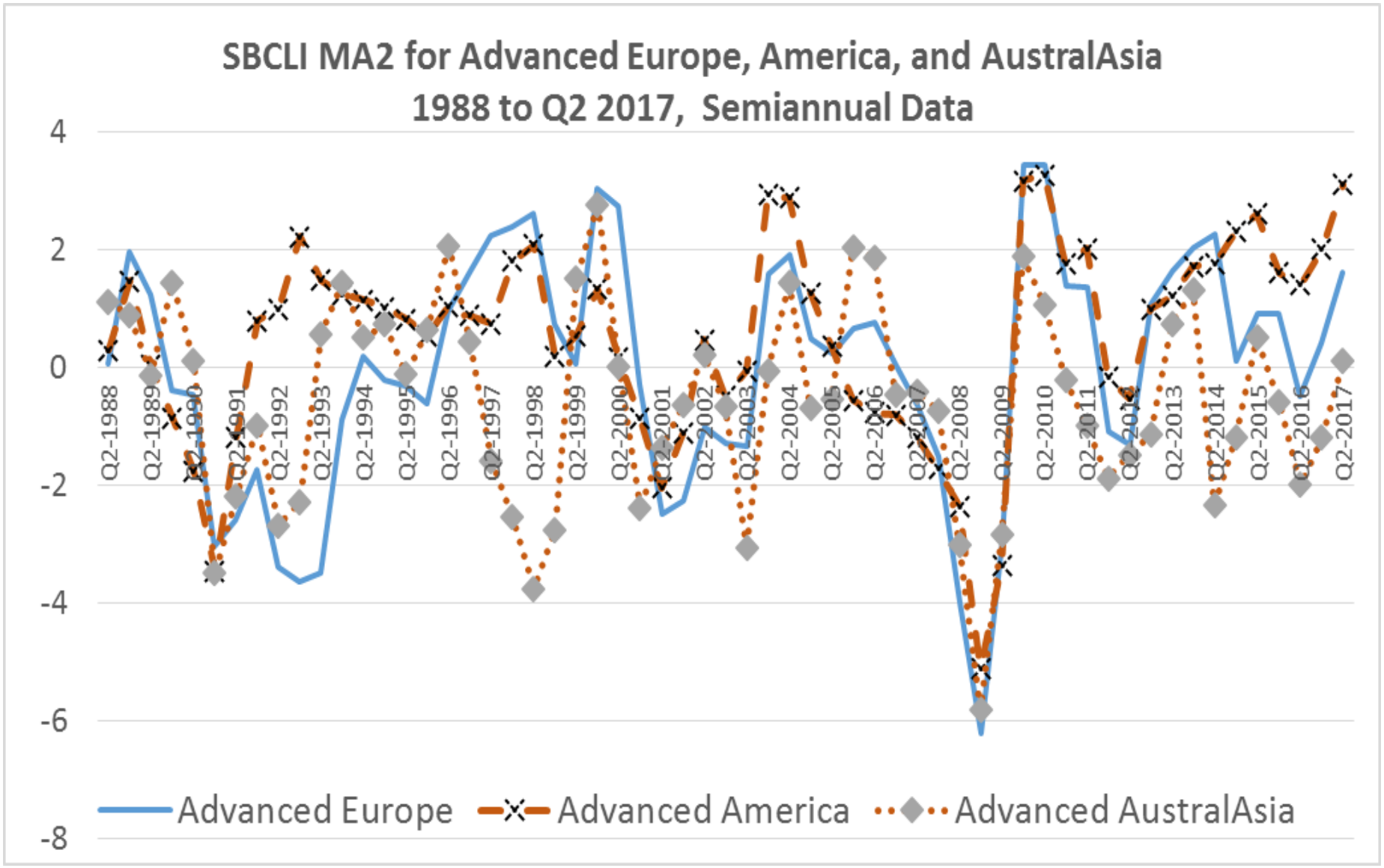
For a normal distribution, Abs(Z)>1 about 1/3 time,

Abs(Z) >2 about 5% time

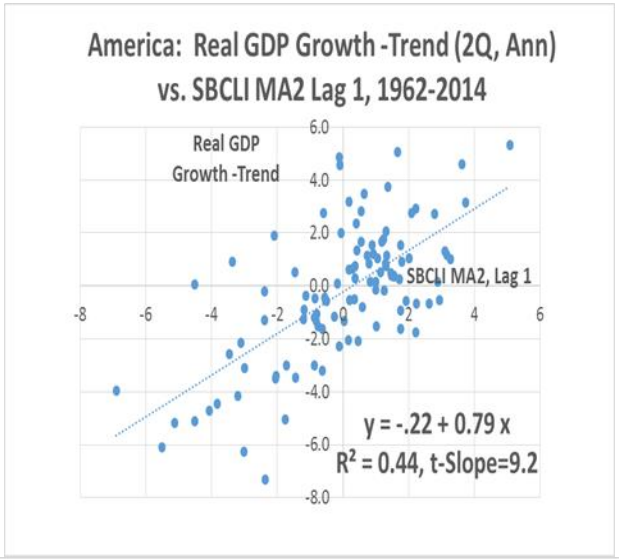
- Simple Stocks, Bonds, Consumers (SBCLI) index proposed is (for advanced economies):

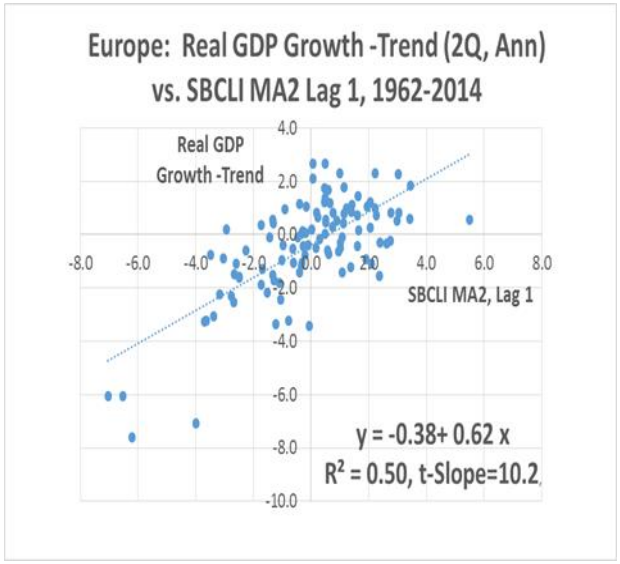
SBCLI = 2*Z(RlStock) + 1*Z(Slope) + 1* Z(Cons Dev'n)

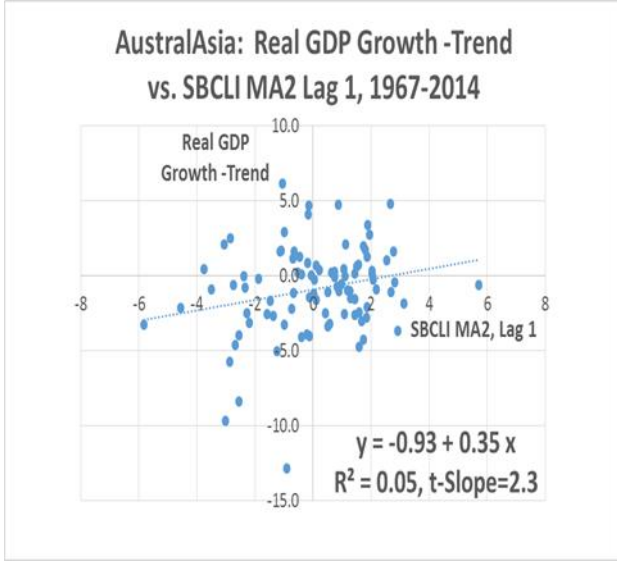


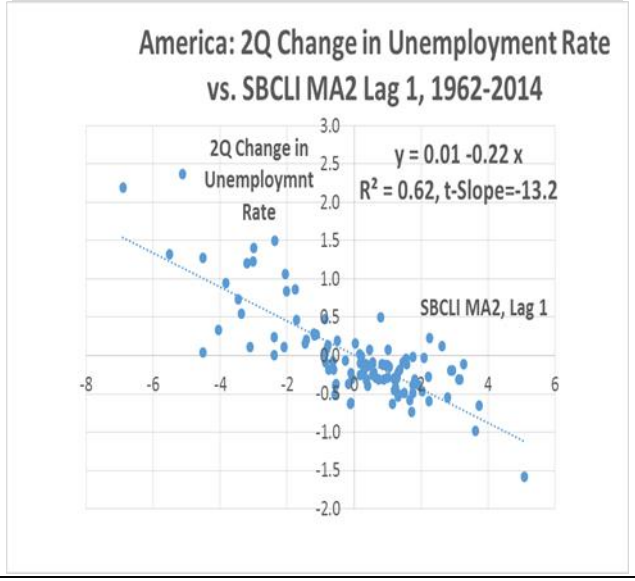


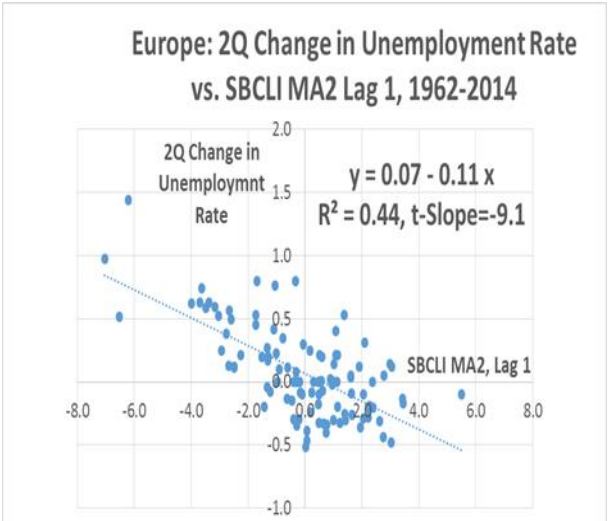
In the 3 Mega-Economies (America, Europe, AustralAsia), the SBCLI shows a significant leading relationship with GDP and Unemployment.











G-7 Economies

Impact of Consumer Signal on Explanatory Power: Correlation of Forecasts with Actuals 2 to 4 Quarters Later
Standard Period from 2007Q1-2015 Q1 Covering the Great Recession of 2008/9 and Sovereign Debt Crisis 2011-2015

G-7 Country	Begin Date: / Ending: 2015-Q2	2-Quarter Forecasts					4-Quarter Forecasts				
		Stocks + Bond Slope	Stocks + Consumers	Stocks, Bonds Consumers	OECD* Leading Indicators	SBCLI-LEI	Stocks + Bond Slope	Stocks + Consumers	Stocks, Bonds Consumers	OECD* Leading Indicators	SBCLI-LEI
United States	2007-Q1	0.68	0.77	0.77	0.74 *	0.03	0.57	0.66	0.74	0.64 *	0.10
Canada	2007-Q1	0.56	0.54	0.60	0.69 **	-0.09	0.46	0.24	0.42	0.55 **	-0.13
France	2007-Q1	0.60	0.66	0.64	0.65	-0.01	0.63	0.58	0.66	0.63	0.03
Germany	2007-Q1	0.55	0.53	0.52	0.57	-0.05	0.51	0.43	0.52	0.48	0.04
Italy	2007-Q1	0.49	0.56	0.54	0.58	-0.04	0.55	0.51	0.57	0.54	0.03
United Kingdom	2007-Q1	0.64	0.63	0.69	0.56	0.13	0.58	0.42	0.57	0.54	0.03
Japan	2007-Q1	0.46	0.45	0.44	0.41	0.03	0.33	0.38	0.38	0.21	0.17
Averages		0.57	0.59	0.60	0.60	0.00	0.52	0.46	0.55	0.51	0.04

*For USA, Conference Board's LEI is used, as it has higher correlations than the OECD's Leading Index.

**For Canada, note that the MA2 forecasts for Stocks and Bonds and SBCLI are worse than not using the moving average. Use of just the latest observation would increase correlations from 0.56 to 0.63, 0.54 to 0.73 and 0.60 to 0.72, respectively, and 0.46 to 0.50 , 0.24 to 0.48, and 0.42 to 0.56 for 4 quarter forecasts.

SBCLI Predicts Major Drawdown Risk Better Than VIX

	United States	Correlations		9/23/2017 10:46
	Hist Vol L12	Hist Vol L24	VIX Eoqm	SBCLI MA2
Real Stock Mkt Drawdown %	-0.48	-0.46	-0.48	0.37
Next 4Q Chg SP500 Drawdown	0.26	0.31	0.17	0.16
	Hist Vol L12	Hist Vol L24	VIX Eoqm	SBCLI MA2
Unemployment Drawdown	-0.58	-0.64	-0.47	0.42
Next 4Q dUnemploymt Drawdo	-0.11	0.06	-0.31	0.60
	Hist Vol L12	Hist Vol L24	VIX Eoqm	SBCLI MA2
Next 4Q GDP-Trend	0.03	0.02	-0.10	0.53
Next 8Q GDP-Trend	-0.26	-0.15	-0.23	0.79
Next 12Q GDP-Trend	-0.35	-0.35	-0.24	0.63
	Hist Vol L12	Hist Vol L24	VIX Eoqm	SBCLI MA2
Next 12 Mos Volatility	0.28	0.02	0.48	-0.42
Next 24 Mos Volatility	0.14	-0.03	0.32	-0.43

What are 17 Trillion Dollar Global Economies SBCLI Risks Today?

Summary of Components of Breeden's Stocks, Bonds, Consumers Leading Indexes for 17 TDEs

Douglas T. Breeden, Duke University and Amundi Pioneer

9/21/2017 22:59

	GDP Trend Growth 10 Yr, Pct	GDP Sensitivity to SBCLI Pt	Stock Market Z-Scores (x			Bond Market Z-Scores			Consumer Z-Scores			Total SBCLI			Implied GDP Growth Forecast
			12/30/16	7/7/17	8/24/17	12/30/16	7/7/17	8/24/17	2016-Q4	2017-Q	2017-Q2	12/30/16	7/7/17	8/24/17	
United States	1.4	0.50	0.8	2.5	2.6	0.3	-0.1	-0.3	1.8	0.5	0.8	3.0	3.2	3.1	3.0
Canada	1.7	0.41	1.5	1.2	1.3	-0.2	-0.3	-0.3	1.0	1.2	2.3	2.3	3.2	3.3	3.0
Brazil	3.0	1.03	1.6	2.2	4.3	-0.6	-0.1	0.1	-2.1	-2.3	-0.6	-1.1	1.5	3.8	7.0
Mexico	2.3	0.42	-0.5	0.9	1.3	0.0	0.3	0.2	0.7	0.2	0.0	0.2	1.1	1.5	2.9
France	0.7	0.36	1.4	2.4	2.3	-0.3	-0.3	-0.6	0.9	0.9	-0.1	2.1	1.9	1.6	1.3
Germany	1.4	0.66	1.5	2.8	2.5	-0.5	-0.1	-0.6	0.7	0.4	0.6	1.7	3.2	2.5	3.0
Italy	-0.6	0.53	0.8	2.0	2.4	0.0	0.0	0.0	1.3	1.3	1.3	2.1	3.3	3.7	1.4
Spain	0.3	0.91	0.5	2.1	1.9	0.0	0.0	0.0	1.7	1.1	0.6	2.2	2.7	2.6	2.6
United Kingdon	1.0	0.46	2.6	3.3	3.5	0.3	0.2	-0.1	0.9	0.3	-0.3	3.8	3.2	3.1	2.4
Russia	2.4	1.62	1.7	0.0	0.6	-1.2	-1.0	-1.0	-1.0	-0.8	-0.3	-0.5	-1.3	-0.8	1.2
Turkey	3.8	0.76	-0.6	2.0	3.1	0.2	0.3	0.3	0.1	0.0	-0.4	-0.4	1.9	3.0	6.1
Japan	0.5	0.34	1.5	2.1	1.7	-1.1	-1.4	-1.5	0.4	0.1	0.7	0.8	1.3	0.9	0.8
Australia	3.3	0.29	0.9	1.0	1.2	0.7	1.0	1.2	0.2	0.2	-0.2	1.8	1.8	2.1	3.9
South Korea	2.7	0.07	0.0	2.5	2.4	-0.6	0.1	0.1	-0.4	-0.6	-0.4	-0.9	2.1	2.1	2.8
China*	7.0	0.72	0.2	0.3	0.4	0.1	-0.8	-1.2	0.5	0.4	0.6	0.8	0.1	-0.2	6.9
India	7.4	0.34	0.0	1.8	1.9	-0.9	-1.0	-1.1	-1.5	-1.2	-2.0	-2.4	-1.2	-1.2	7.0
Indonesia	5.6	0.40	0.6	1.7	1.9	0.4	0.6	0.6	-0.3	-0.6	-0.6	0.7	1.7	1.9	6.4

*China trend is 3 years vs. 10 years for other countries.

III. Summary of SBCLI Measure of Global Risks

1. VIX was shown to forecast next 1 year volatility of stock returns better than historic stock volatility, with 0.48 vs. 0.28 correlation. Traders use their information effectively to improve upon historic volatility levels.

2. SBCLI is better than VIX at forecasting stock return volatility over the longer, 2-year forward time period with correlation of -0.43 vs. 0.32.

3. SBCLI is much better than VIX at forecasting major macroeconomic risks such as changes in the unemployment rate "drawdown" and deviations of real GDP growth from trends. Correlation differences are approximately 0.60 for SBCLI vs. 0.30 for VIX.

4. Current SBCLI readings show strong economies in the Americas, Europe and AustralAsia, with many SBCLI readings in the 2.0 to 3.8 range. Only Russia, China and India show slightly below-trend growth forecasts. SBCLI for Brazil, Italy and Turkey have improved most in recent months.

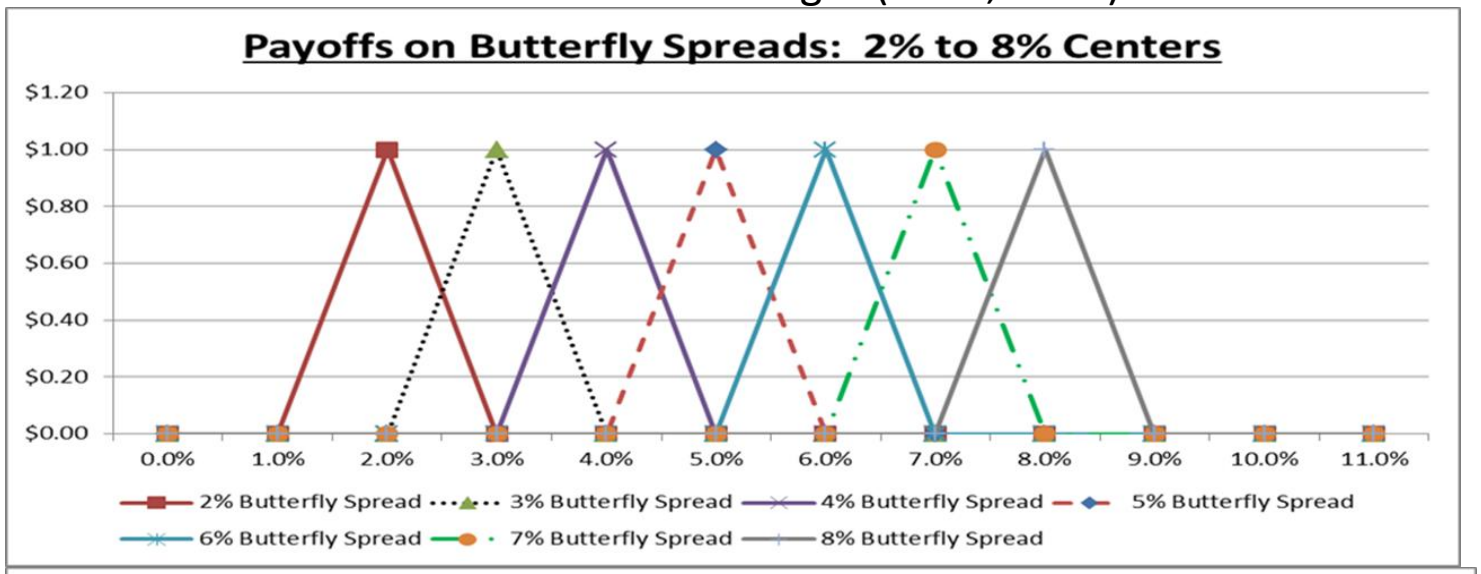
IV. Measuring Global Risks.

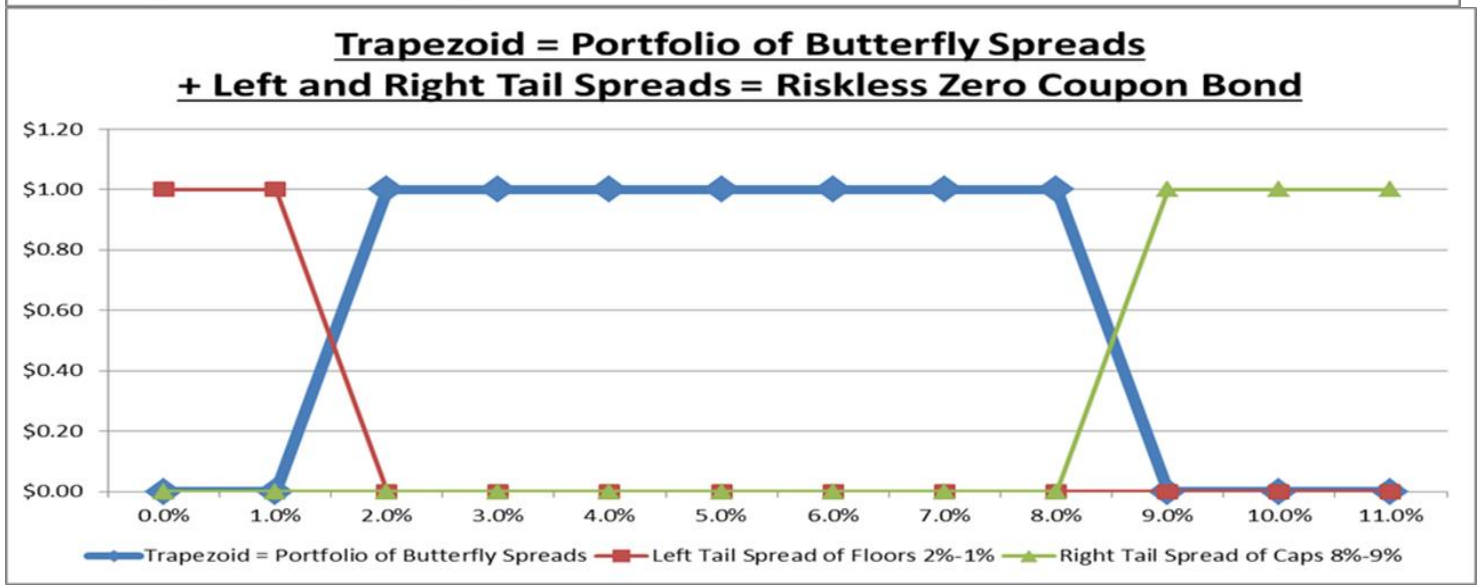
How to Find Interest Rate Insurance Prices From Option Prices:

*See Ross (1976), Quarterly Journal of Economics article "Options and Efficiency" and Breeden and Litzenberger (1978) Journal of Business article, "Prices of State-Contingent Claims Implicit in Option Prices." B-L's MIT working paper in 2013 on "Central Bank Policy Impacts on the Distribution of Future Interest Rates" gives the method for calculations in this talk. .

Butterfly Spreads of Caplets and Floorlets

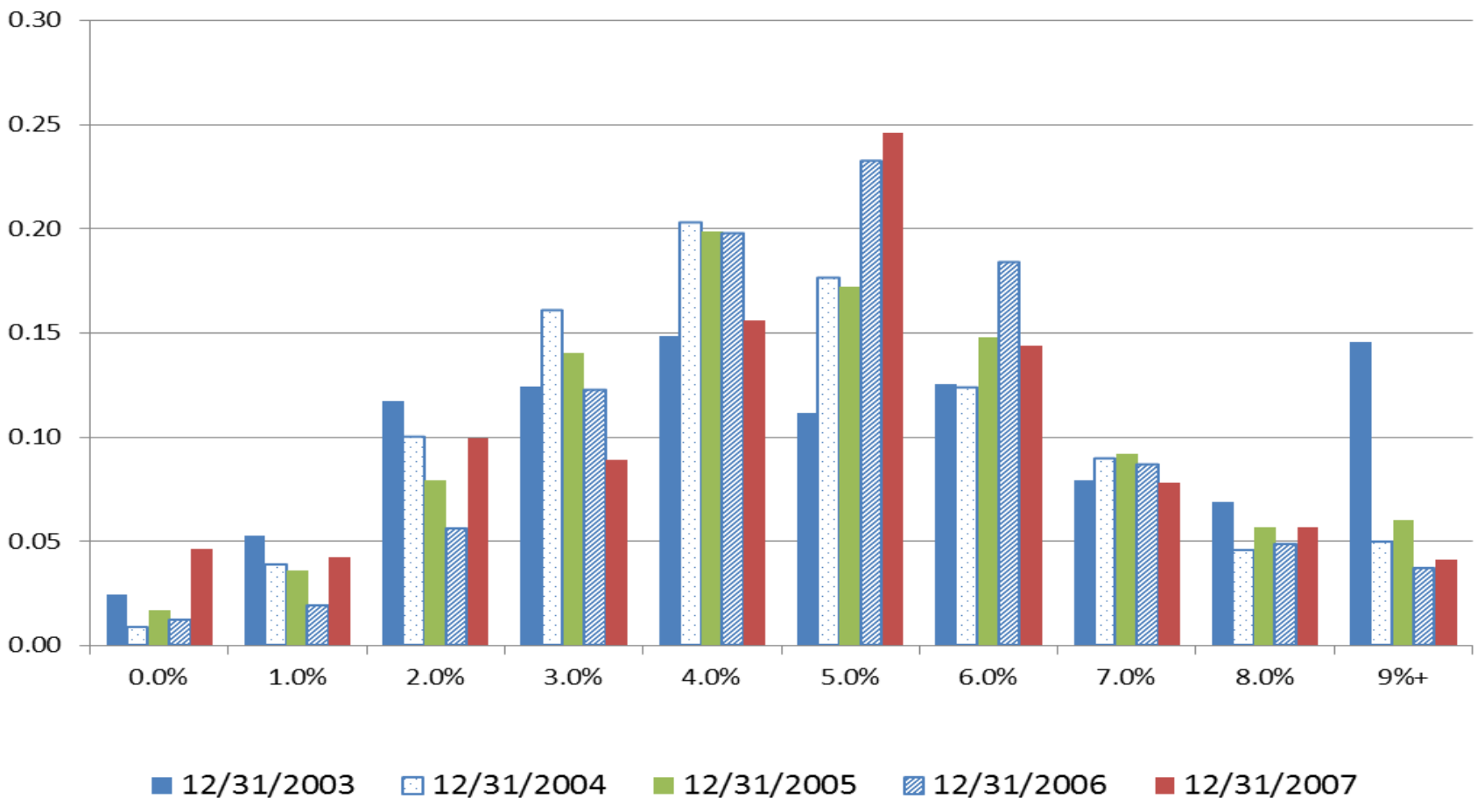
Breeden and Litzenberger (1978, 2014)





USA Insurance Prices for 3-Month LIBOR in 5 Years, as of December 31, 2003, 2004, 2005, 2006, 2007:

Relatively Symmetric Distributions



True Probabilities vs.

Insurance Prices or "Risk Neutral Probabilities"

Insurance prices or "risk neutral probabilities" differ from true, objective probabilities, because investors price assets higher for those that pay off most when times are bad (negative beta). Thus, their insurance prices (risk neutral probabilities) exceed their true probabilities.

States that correspond to good economies will have lower insurance prices, and their insurance prices will underestimate the true probabilities.

Equilibrium Price/Probability Ratios

In state preference and in CRRA-Lognormal model:

$$\frac{\phi^*_{tr_j}}{\pi_{tr_j}} = \frac{E\left[\tilde{u}'_{ts} \middle| r_j\right]}{E[\tilde{u}'_t]} \tag{12}$$

$$\log\left(\frac{\phi^*_{ts}}{\pi_{ts}}\right) = \gamma\left[\mu_t - g_{ts} - \frac{1}{2}\gamma\sigma_c^2\right]t \tag{19}$$

e

As expected, higher growth states for consumption have lower $\left(\frac{\phi^*_{ts}}{\pi_{ts}}\right)$ ratios.

Illustration of True Probabilities Related to Risk Neutral Probabilities

True probability = K*Risk Neutral x exp(Gamma*(gts - mu))

Assumes: CRRA-Lognormal real growth model

Real Growth on Nominal Rate: 1998 to 2011 Data

Intercept	-3.71	(t= -2.2)
Slope	1.42	(t= 3.8)
MuCgrow	3	

Nominal Rate	Real Growth	Relative Risk Aversion (Gamma) 2	4	8
		Ratio of True Probability to Risk Neutral*		
1	-2.29	0.90	0.81	0.65
2	-0.87	0.93	0.86	0.73
3	0.55	0.95	0.91	0.82
4	1.97	0.98	0.96	0.92
5	3.39	1.01	1.02	1.03
6	4.81	1.04	1.08	1.16
7	6.23	1.07	1.14	1.29
8	7.65	1.10	1.20	1.45
9	9.07	1.13	1.27	1.63
10	10.49	1.16	1.35	1.82

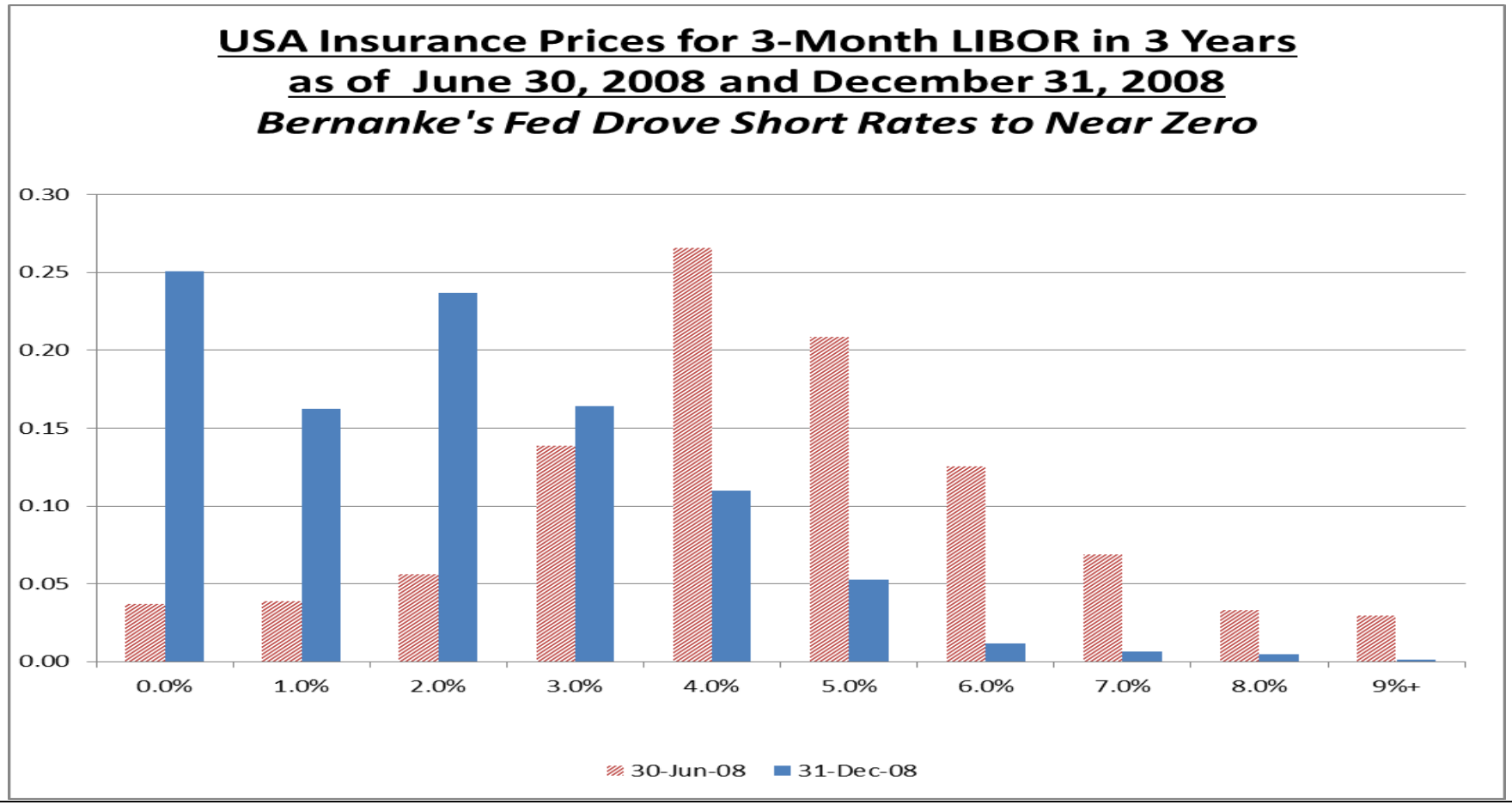
*=Up to a scalar multiple

Real Growth on Nominal Rate: 1977 to 1997 Data

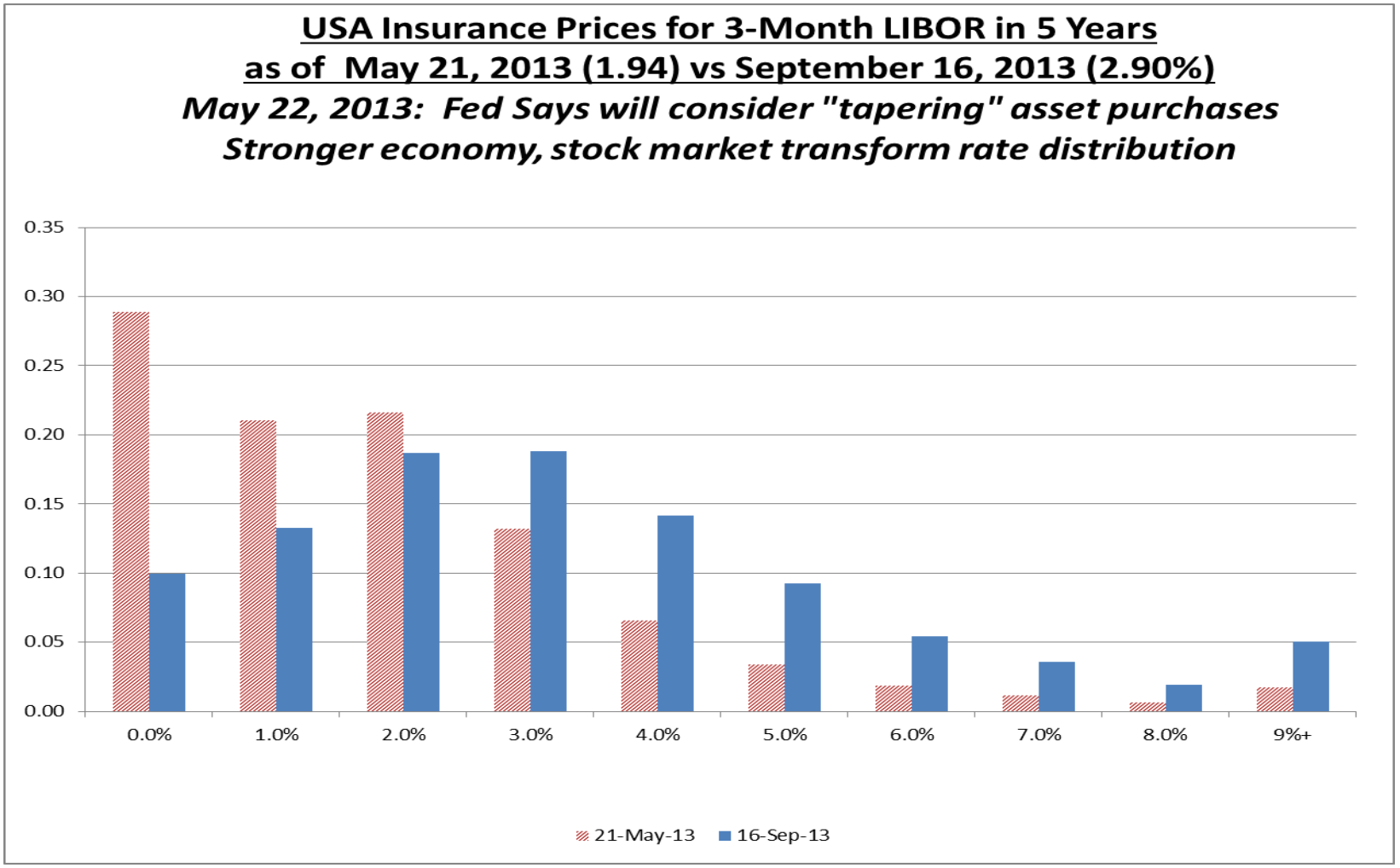
Intercept	4.11	(t= 3.2)
Slope	-0.12	(t= -0.8)
MuCgrowt	3	

Nominal Rate	Real Growth	Relative Risk Aversion (Gamma) 2	4	8
		Ratio of True Probability to Risk Neutral*		
1	3.99	1.02	1.04	1.08
2	3.87	1.02	1.04	1.07
3	3.75	1.02	1.03	1.06
4	3.63	1.01	1.03	1.05
5	3.51	1.01	1.02	1.04
6	3.39	1.01	1.02	1.03
7	3.27	1.01	1.01	1.02
8	3.15	1.00	1.01	1.01
9	3.03	1.00	1.00	1.00
10	2.91	1.00	1.00	0.99
11	2.79	1.00	0.99	0.98
12	2.67	0.99	0.99	0.97
13	2.55	0.99	0.98	0.96
14	2.43	0.99	0.98	0.96
15	2.31	0.99	0.97	0.95
16	2.19	0.98	0.97	0.94

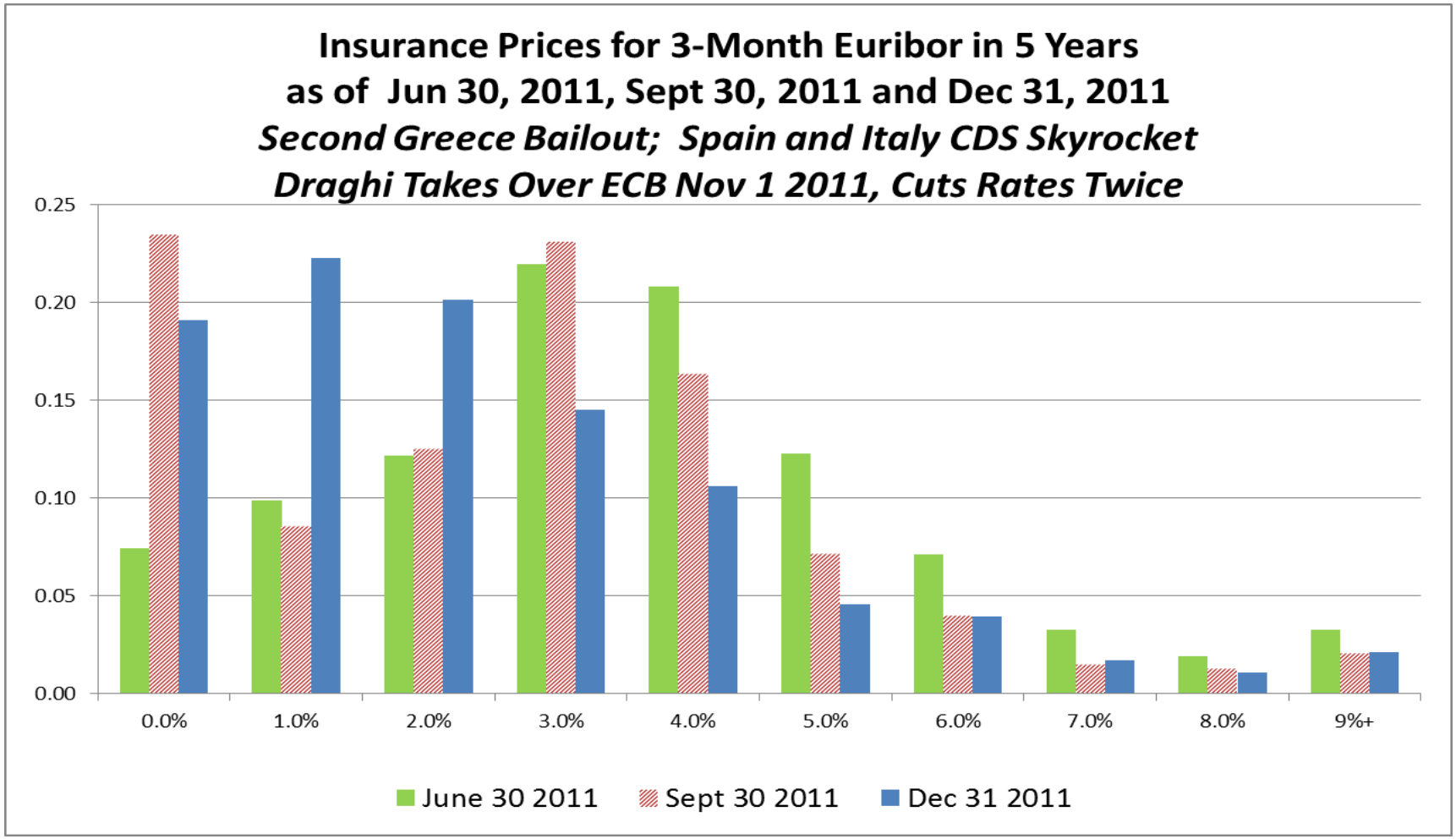
2008: U.S. Rate Distribution Transformed from Symmetric to Positive Skewness (Concentrated near zero, but long right tail)



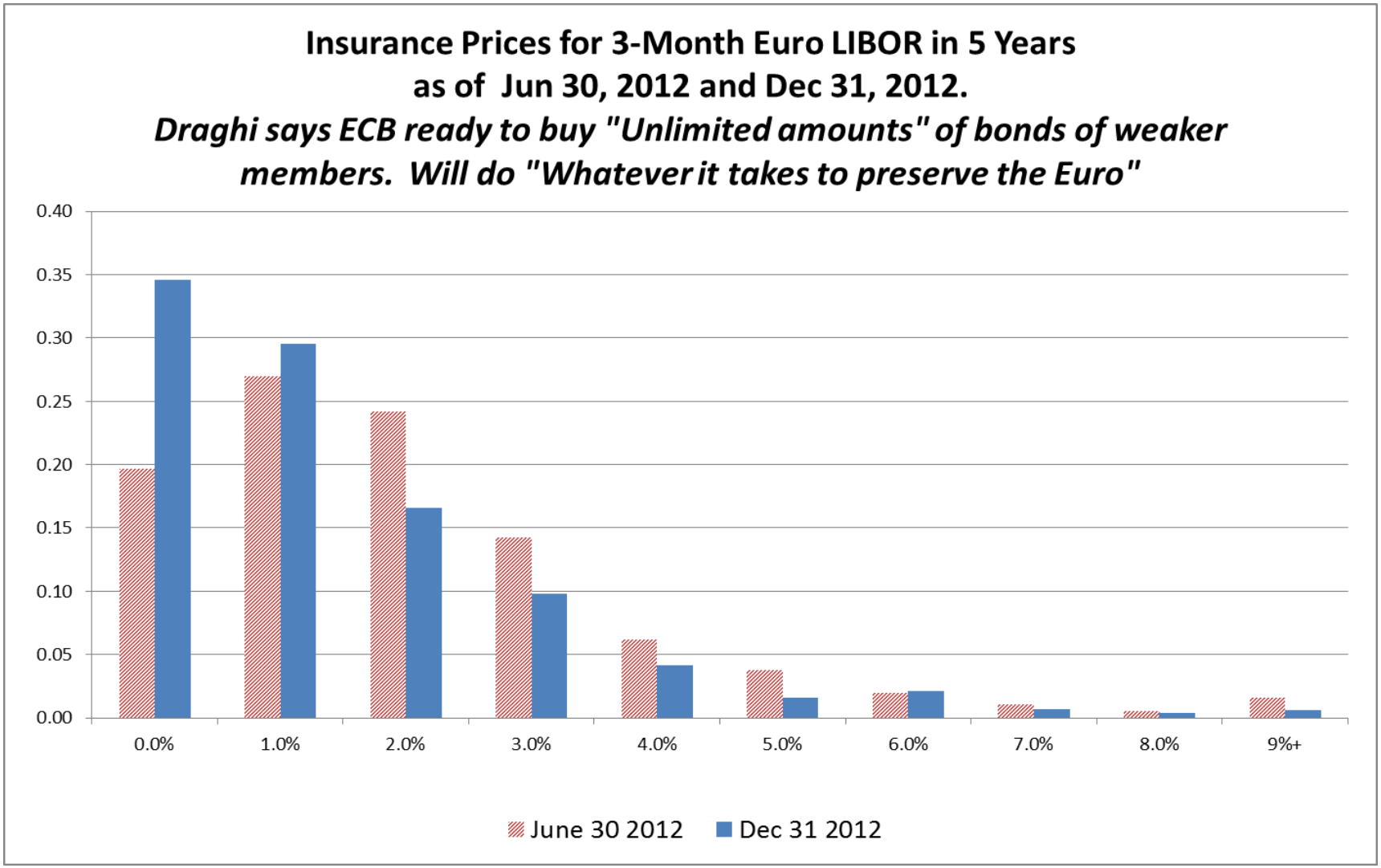
Summer 2013 Tapering Announcements: Stronger economy shifts distribution towards symmetry



2011 Sovereign Debt Crisis: Draghi ECB cuts rates sharply. Massive shift in Euribor interest rate distribution to positive skewness like U.S.



Draghi Rescues the Euro in 2012 with "Whatever it takes…"



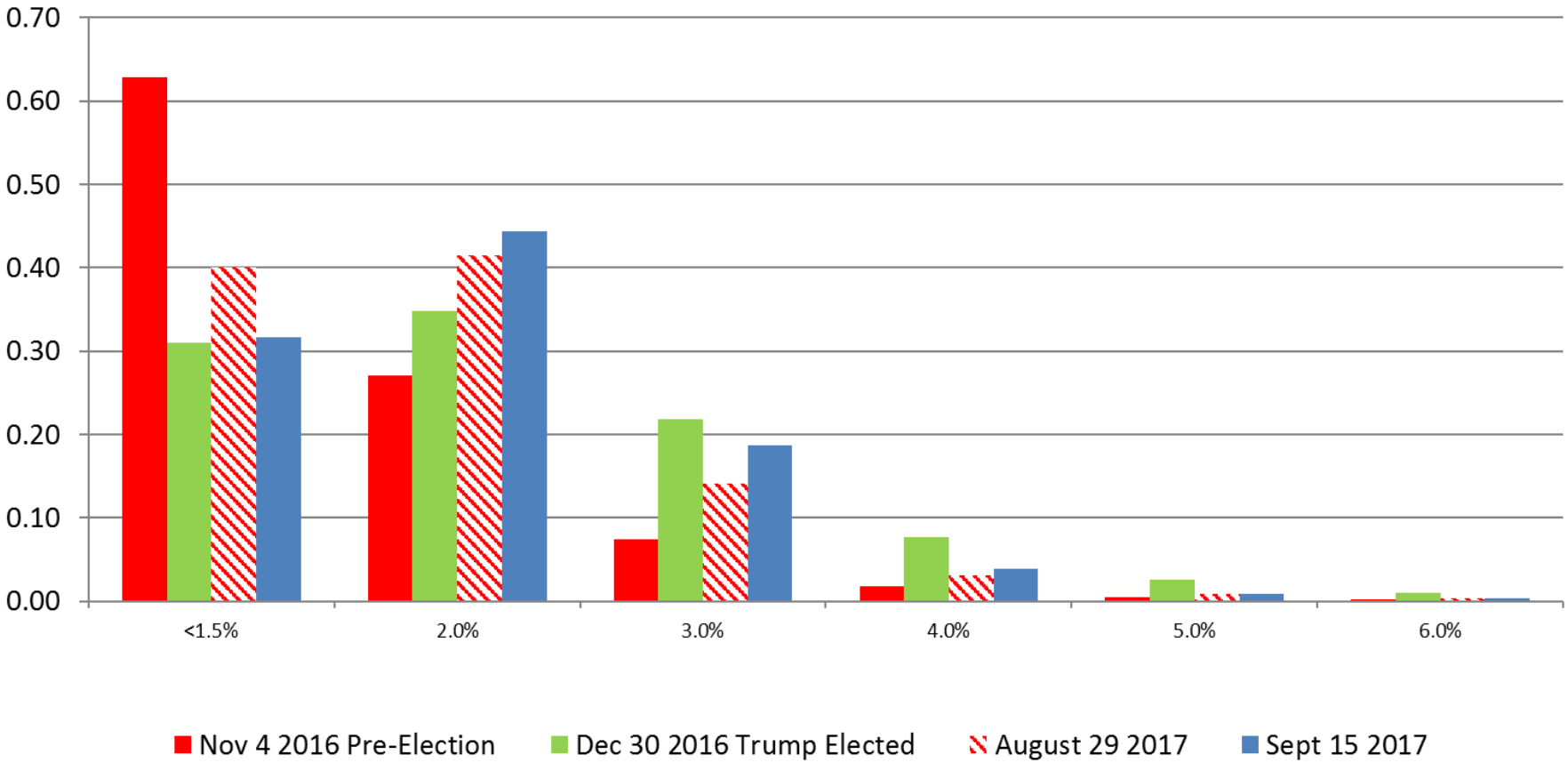
V. What are interest rate options markets saying now in the USA, the Eurozone and the UK?

USA Insurance Prices for 3-Month LIBOR in 3 Years

Nov 4 (1.78% 10 Yr), Dec 30 2016 (2.44%), August 29 (2.13%), Sept 15 (2.20%)

Sept 15, 2017: Despite North Korea nuclear, stocks and rates move back up.

3-yr dist'n shifts towards symmetry/normalization.

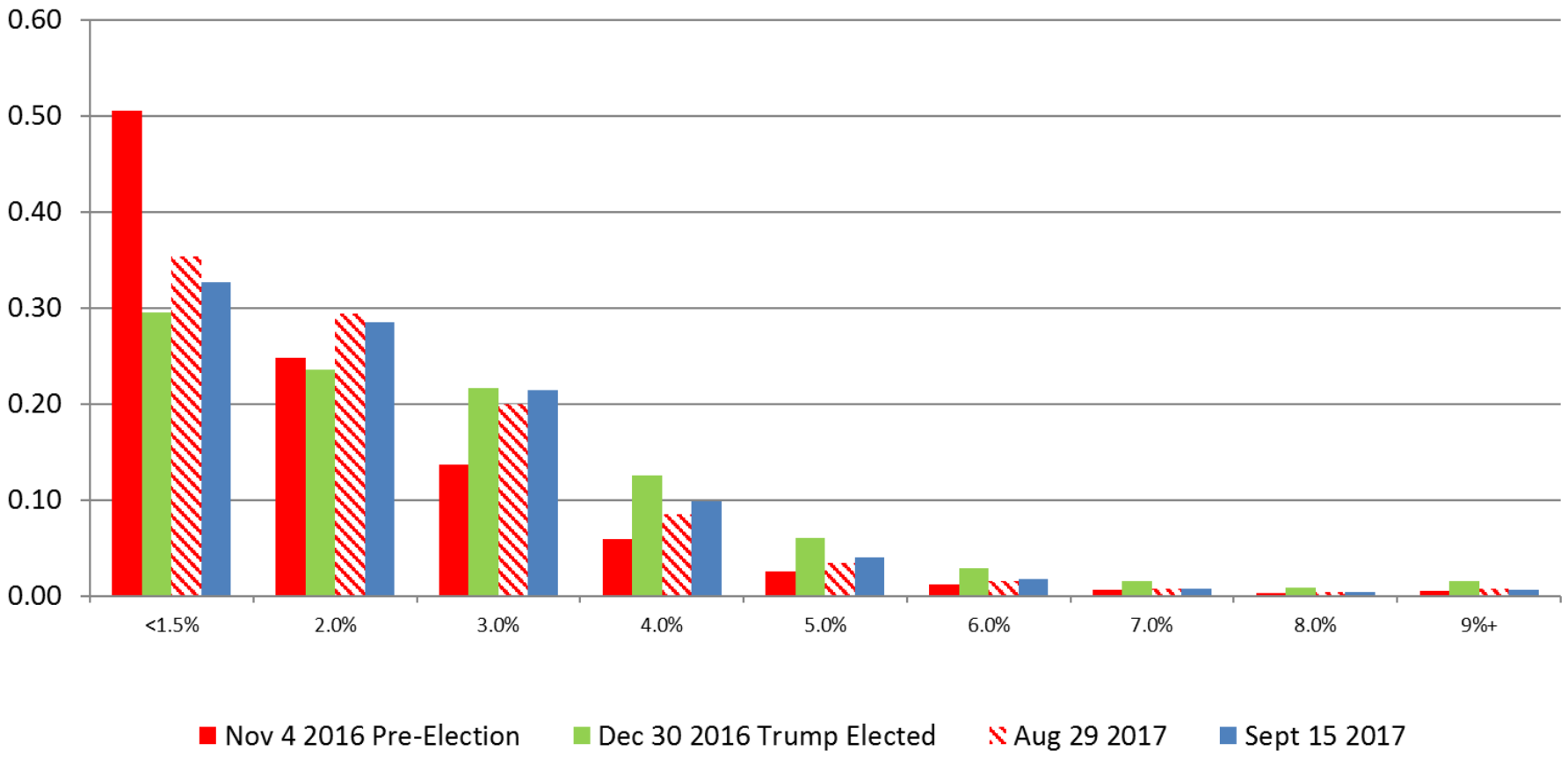


USA Insurance Prices for 3-Month LIBOR in 5 Years

Nov 4 (1.78% 10 Yr), Dec 30 2016 (2.44%), Aug 29 (2.13%), Sept 15 2017 (2.20%)

Sept 15 2017: NoKo nuclear worries keep 5-yr distn positively skewed.

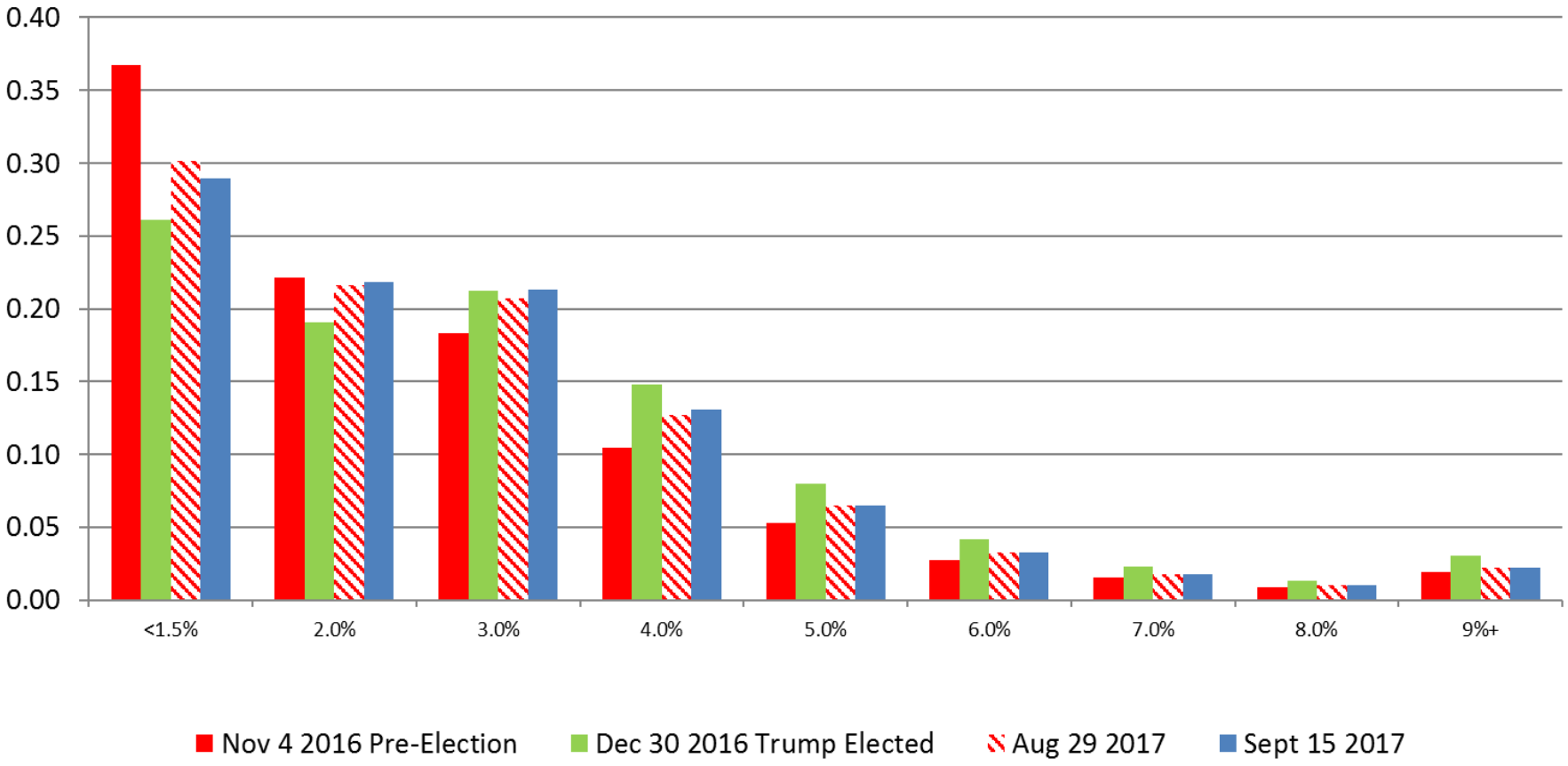
High risk aversion in high price for 0-1.5% rate hedge



USA Insurance Prices for 3-Month LIBOR in 8-10 Years

Nov 4 (1.78% 10 Yr), Dec 30 2016 (2.44%), Aug 29 (2.13%), Sept 15 2017 (2.20%)

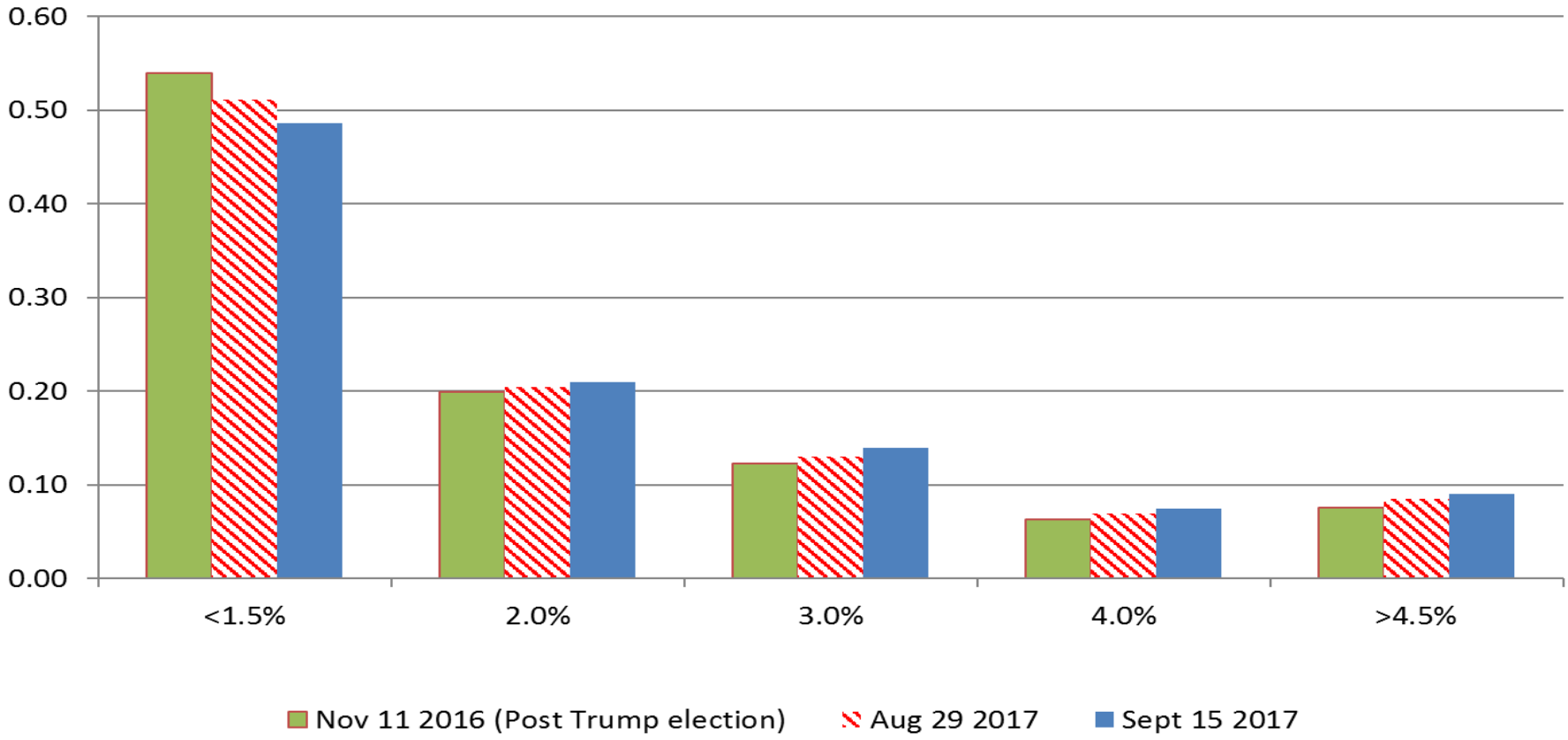
Aug 29-Sept 15 2017: NoKo nuclear worries shift long-term dist'n from uniform 0-3.5% to positive skew, high risk premium



Euro Insurance Prices for 3-Month Euribor in 8-10 Years

Nov 11 (10 yr Bund= 0.31%), Aug 29 (0.34%), September 15 2017 (0.43%)

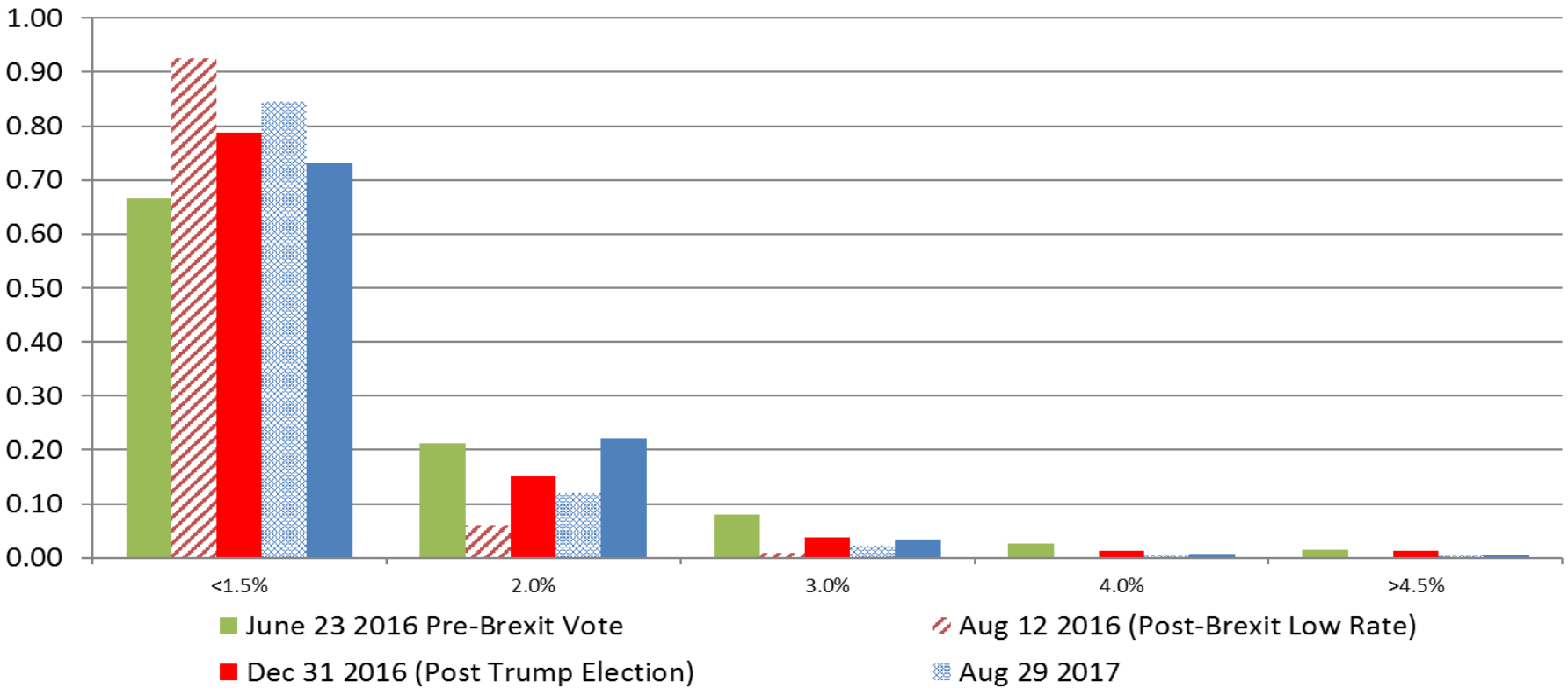
Sept 15 2017: Despite NoKo nuclear worries, Draghi's ECB likely tapering moves Euro long-term distn towards normalization.



UK Insurance Prices for 3-Month Rate in 3 Years

Jun 23 2016 (1.37% 10 Yr), Aug 12 (0.52%),Dec 31(1.24%), Aug 29 (1.00%), Sept 15 2017 (1.31%)

Sept 15 2017: NoKo nuclear worries offset by BoE indications of liftoff in rates. Rate distn shifts higher.

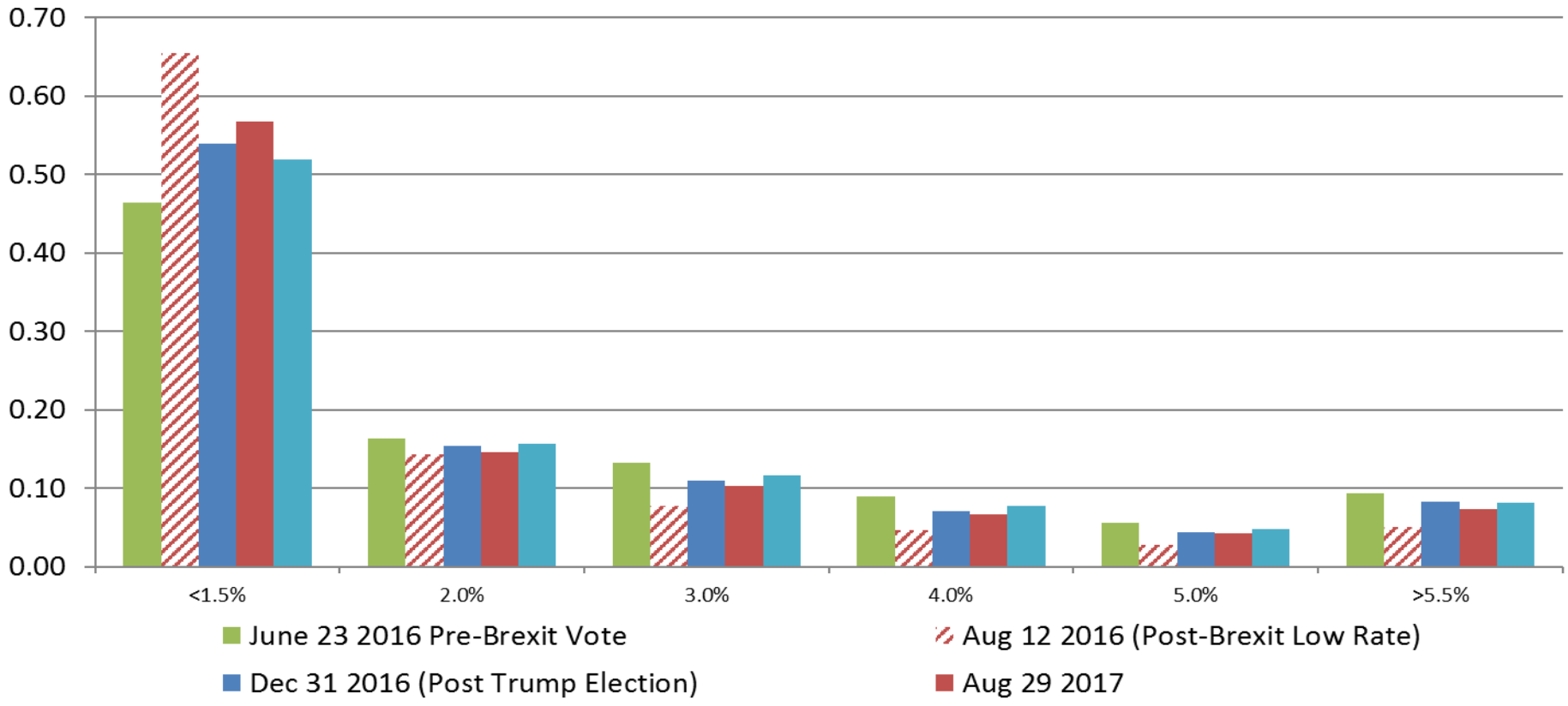


UK Insurance Prices for 3-Month Rate in 8-10 Years

Jun 23 2016 (1.37% 10 Yr), Aug 12 (0.52%),Dec 31(1.24%), Aug 29 (1.00%), Sept 15 2017 (1.31%)

Sept 15 2017: BoE says UK economy is strong enough for liftoff.

Long-term distribution shifts slightly higher



V. Summary: Extracting Interest Rate Insurance Prices from Interest Rate Options Prices

- Using Breeden-Litzenberger butterfly spreads of time spreads of interest rate caps and floors gives interest rate insurance prices. These were shown to reflect major moves by the U.S. Federal Reserve, the European Central Bank and the Bank of England in the Great Recession of 2008-2009 and in the Sovereign Debt Crisis of 2011-2013.

- Insurance prices (Arrow's "state prices") reflect both objective probabilities and marginal utilities in the different economic scenarios. Interest rates likely to occur in recessionary economies have higher prices, as they are used to hedge major macroeconomic risks.

- Current pricing in the USA, Eurozone and the UK shows movements towards normalized interest rate distributions in 3, 5 and 8-10 years. However, prices are often very high for very low rate scenarios in 5-10 years, which likely reflects high risk aversion and pricing of recession risks.

VI. Implicit Insurance Prices from Options on Stock Prices for the S&P500.

Breeden and Litzenberger (1978, 2014) technique.

Note: 2005-2006: Low price paid for left tail insurance. High right tail.

S&P 500 Insurance Prices (Risk-neutral density).

9/22/2017 — Monthend Data from December 2004. Uses Breeden-Litzenberger (2014) technique — **Option: 12 Months TTM**

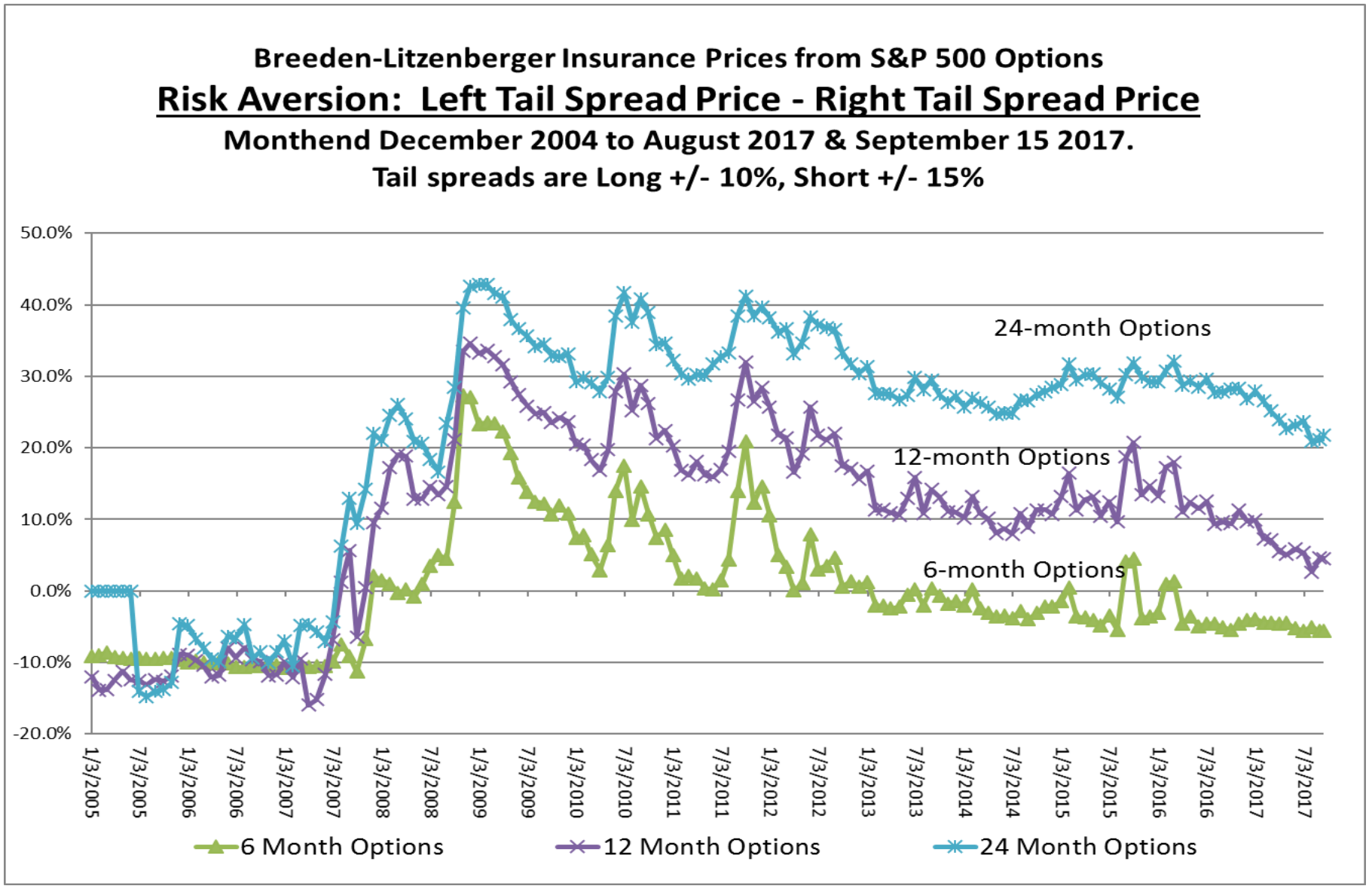
		$90%-$85 Puts				ATM				$120-$125 Calls			$110-$115 Calls	
	ATM	S&P 500	**Left Tail**	90	95	100	105	110	115	120	Right Tail	Sum	**Right Tail**	**Left Tail**
Date	Implied σ	Spot Index	**Spread**	Butterfly	Butterfly	Butterfly	Butterfly	Butterfly	Butterfly	Butterfly	Spread		**Spread**	**-Right Tail**
1/3/2005	14.8	1202.1	**14.0%**	11.8%	13.7%	13.8%	12.3%	8.4%	7.8%	6.2%	12.0%	100.0%	**26.0%**	**-12.0%**
12/30/2005	14.3	1248.3	**11.3%**	15.4%	17.7%	15.5%	12.0%	7.8%	5.9%	4.2%	10.2%	100.0%	**20.3%**	**-9.0%**
6/30/2006	14.5	1270.2	**11.5%**	16.1%	18.1%	14.5%	11.8%	7.2%	5.8%	4.3%	10.7%	100.0%	**20.8%**	**-9.3%**
12/29/2006	14.0	1418.3	**10.1%**	15.9%	18.6%	15.6%	12.2%	7.7%	5.8%	4.2%	10.0%	100.0%	**19.9%**	**-9.9%**
6/29/2007	15.8	1503.4	**14.9%**	15.8%	16.6%	13.2%	11.0%	6.9%	5.7%	4.3%	11.7%	100.0%	**21.7%**	**-6.8%**
12/31/2007	22.2	1468.4	**32.7%**	13.1%	11.9%	8.5%	7.7%	5.0%	4.4%	3.6%	13.1%	100.0%	**21.1%**	**11.6%**
3/31/2008	23.8	1322.7	**39.0%**	11.9%	10.6%	7.4%	6.9%	4.2%	4.0%	3.3%	12.8%	100.0%	**20.1%**	**18.9%**
6/30/2008	22.3	1280.0	**34.6%**	13.1%	11.6%	8.5%	7.4%	4.8%	4.2%	3.4%	12.3%	100.0%	**20.0%**	**14.6%**
9/30/2008	27.0	1166.4	**42.7%**	10.1%	9.1%	6.4%	6.3%	4.0%	3.8%	3.3%	14.4%	100.0%	**21.5%**	**21.2%**
10/31/2008	39.4	968.8	**55.0%**	6.5%	6.1%	3.8%	4.5%	2.5%	2.8%	2.7%	16.0%	100.0%	**21.5%**	**33.5%**
11/28/2008	41.6	896.2	**56.3%**	6.0%	5.7%	3.7%	4.2%	2.5%	2.8%	2.6%	16.3%	100.0%	**21.7%**	**34.6%**
12/31/2008	36.3	903.3	**53.9%**	7.0%	6.5%	4.3%	4.7%	2.9%	3.0%	2.7%	15.0%	100.0%	**20.7%**	**33.2%**
1/30/2009	37.1	825.9	**54.2%**	7.2%	6.4%	4.3%	4.6%	2.8%	2.9%	2.7%	14.9%	100.0%	**20.5%**	**33.7%**
2/27/2009	36.9	735.1	**53.6%**	7.1%	6.4%	4.5%	4.6%	3.0%	3.0%	2.7%	15.1%	100.0%	**20.8%**	**32.8%**
3/31/2009	36.9	797.9	**53.1%**	6.9%	6.3%	4.6%	4.6%	3.0%	3.0%	2.8%	15.7%	100.0%	**21.5%**	**31.6%**
6/30/2009	26.8	919.3	**44.8%**	10.7%	9.2%	6.6%	6.0%	3.9%	3.5%	3.0%	12.4%	100.0%	**18.9%**	**25.9%**
12/31/2009	22.8	1115.1	**38.6%**	13.0%	11.1%	8.1%	6.8%	4.3%	3.8%	3.1%	11.1%	100.0%	**18.1%**	**20.5%**
6/30/2010	28.9	1030.7	**48.0%**	10.7%	9.0%	5.9%	5.6%	3.2%	3.2%	2.8%	11.7%	100.0%	**17.7%**	**30.3%**
12/31/2010	21.4	1257.6	**36.9%**	14.6%	12.2%	8.4%	7.1%	4.2%	3.7%	3.0%	10.0%	100.0%	**16.7%**	**20.2%**
6/30/2011	19.4	1320.6	**32.5%**	16.8%	13.7%	9.9%	7.4%	4.3%	3.7%	2.9%	8.8%	100.0%	**15.4%**	**17.0%**
7/29/2011	20.7	1292.3	**35.7%**	15.4%	12.7%	8.7%	7.2%	4.1%	3.7%	3.0%	9.7%	100.0%	**16.3%**	**19.5%**
8/31/2011	25.3	1218.9	**43.4%**	12.6%	10.2%	7.2%	6.1%	3.6%	3.4%	2.8%	10.5%	100.0%	**16.7%**	**26.7%**
9/30/2011	30.8	1131.4	**50.4%**	9.4%	8.1%	5.3%	5.3%	3.0%	3.1%	2.8%	12.5%	100.0%	**18.4%**	**32.0%**
12/30/2011	24.1	1257.6	**42.4%**	13.2%	10.8%	7.1%	6.3%	3.6%	3.4%	2.9%	10.4%	100.0%	**16.7%**	**25.8%**
6/29/2012	21.0	1362.2	**36.8%**	16.1%	12.8%	8.6%	6.9%	3.7%	3.4%	2.8%	8.9%	100.0%	**15.1%**	**21.7%**
12/31/2012	18.7	1426.2	**31.9%**	17.1%	14.0%	10.0%	7.6%	4.2%	3.7%	2.9%	8.6%	100.0%	**15.2%**	**16.7%**
6/28/2013	17.7	1606.3	**30.4%**	17.7%	14.8%	10.3%	7.8%	4.6%	3.7%	2.8%	7.9%	100.0%	**14.5%**	**15.9%**
12/31/2013	15.2	1848.4	**23.3%**	19.8%	17.3%	12.8%	8.7%	5.0%	3.8%	2.7%	6.6%	100.0%	**13.1%**	**10.2%**

2017: Risk aversion (Left Tail minus Right Tail) diminished since China Crash in Aug 2015, but well above risk aversion in 2005-2006

S&P 500 Insurance Prices (Risk-neutral density).

9/22/2017 Monthend Data from December 2004. Uses Breeden-Litzenberger (2014) technique **Option: 12 Months TTM**

		$90%-$85 Puts				ATM				$120-$125 Calls	$110-$115 Calls			
	ATM	S&P 500	**Left Tail**	90	95	100	105	110	115	120	Right Tail	Sum	**Right Tail**	**Left Tail**
Date	Implied σ	Spot Index	**Spread**	Butterfly	Butterfly	Butterfly	Butterfly	Butterfly	Butterfly	Butterfly	Spread		**Spread**	**-Right Tail**
6/30/2014	14.3	1960.2	**20.2%**	21.7%	19.2%	13.1%	8.9%	4.7%	3.6%	2.6%	6.0%	100.0%	**12.2%**	**7.9%**
12/31/2014	17.3	2058.9	**27.0%**	21.0%	16.7%	9.8%	7.8%	3.9%	3.5%	2.8%	7.6%	100.0%	**13.8%**	**13.2%**
6/30/2015	16.6	2063.1	**25.9%**	21.8%	17.4%	9.7%	7.9%	3.8%	3.4%	2.7%	7.3%	100.0%	**13.5%**	**12.5%**
7/31/2015	15.3	2103.8	**22.5%**	22.9%	18.9%	10.9%	8.3%	3.8%	3.4%	2.7%	6.7%	100.0%	**12.8%**	**9.7%**
8/31/2015	19.8	1972.2	**34.0%**	18.1%	14.2%	7.9%	7.2%	3.3%	3.4%	2.9%	9.0%	100.0%	**15.3%**	**18.7%**
9/30/2015	20.2	1920.0	**36.4%**	16.0%	13.1%	7.7%	7.2%	4.0%	3.6%	2.9%	9.2%	100.0%	**15.7%**	**20.8%**
12/31/2015	17.5	2043.9	**27.5%**	21.1%	16.7%	8.9%	7.9%	3.6%	3.5%	2.8%	8.0%	100.0%	**14.3%**	**13.2%**
6/30/2016	17.0	2098.9	**26.1%**	22.3%	17.5%	9.1%	7.9%	3.5%	3.4%	2.7%	7.4%	100.0%	**13.6%**	**12.5%**
10/31/2016	16.8	2126.2	**25.2%**	22.6%	17.8%	9.1%	8.0%	3.5%	3.4%	2.8%	7.7%	100.0%	**13.9%**	**11.3%**
11/30/2016	16.3	2198.8	**23.4%**	22.5%	18.2%	10.3%	8.1%	3.7%	3.5%	2.8%	7.4%	100.0%	**13.7%**	**9.7%**
12/30/2016	16.4	2238.8	**23.5%**	22.4%	18.1%	10.6%	8.1%	3.6%	3.5%	2.8%	7.4%	100.0%	**13.6%**	**9.9%**
1/31/2017	14.9	2278.9	**19.9%**	23.4%	19.8%	12.1%	8.5%	3.8%	3.4%	2.7%	6.5%	100.0%	**12.6%**	**7.3%**
2/28/2017	14.8	2363.6	**19.8%**	23.2%	19.8%	12.2%	8.6%	3.8%	3.5%	2.7%	6.5%	100.0%	**12.7%**	**7.1%**
3/31/2017	13.9	2362.7	**17.5%**	23.7%	20.9%	13.0%	8.8%	4.0%	3.5%	2.6%	6.0%	100.0%	**12.0%**	**5.5%**
6/30/2017	14.1	2423.4	**17.4%**	24.3%	21.3%	12.4%	8.7%	3.9%	3.4%	2.6%	6.0%	100.0%	**12.0%**	**5.3%**
7/31/2017	12.8	2470.3	**13.6%**	24.7%	23.2%	14.5%	9.1%	3.9%	3.3%	2.4%	5.2%	100.0%	**11.0%**	**2.6%**
8/31/2017	13.9	2471.7	**16.4%**	24.6%	21.7%	13.0%	8.7%	3.7%	3.3%	2.5%	5.9%	100.0%	**11.8%**	**4.7%**
9/15/2017	13.9	2500.2	**16.3%**	24.8%	21.9%	12.9%	8.7%	3.8%	3.3%	2.5%	5.9%	100.0%	**11.7%**	**4.5%**

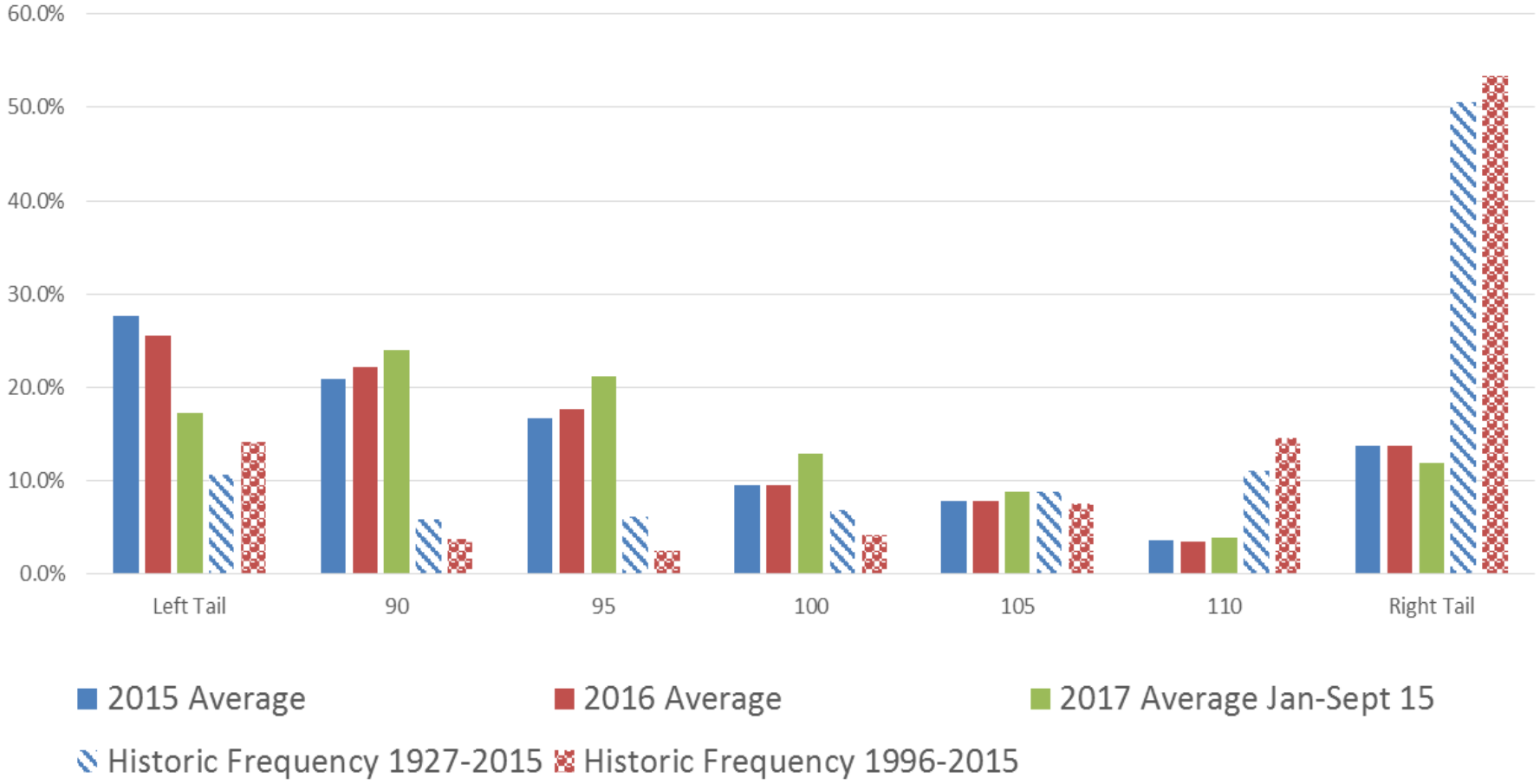


Frequency Distribution of S&P 500 Returns for 3 Sample Perio
and 5 holding periods: (1, 3, 6, 12, and 24 months)

Low	-9999	-12.5	-7.5	-2.5	2.5	7.5	12.5	
High	-12.51	-7.51	-2.51	2.49	7.49	12.49	9999	
3 Month Return								
1927-2015	57	57	132	235	278	191	107	1057
	5.4%	5.4%	12.5%	22.2%	26.3%	18.1%	10.1%	100.0%
1971-2015	19	26	64	138	154	90	49	540
	3.5%	4.8%	11.9%	25.6%	28.5%	16.7%	9.1%	100.0%
1996-2015	12	17	21	57	81	34	18	240
	5.0%	7.1%	8.8%	23.8%	33.8%	14.2%	7.5%	100.0%
6 Month Return								
1927-2015	90	54	109	123	200	177	304	1057
	8.5%	5.1%	10.3%	11.6%	18.9%	16.7%	28.8%	100.0%
1971-2015	27	29	57	68	124	95	140	540
	5.0%	5.4%	10.6%	12.6%	23.0%	17.6%	25.9%	100.0%
1996-2015	15	15	24	25	60	42	59	240
	6.3%	6.3%	10.0%	10.4%	25.0%	17.5%	24.6%	100.0%
12 Month Return								
1927-2015	113	62	65	72	94	117	534	1057
	10.7%	5.9%	6.1%	6.8%	8.9%	11.1%	50.5%	100.0%
1971-2015	51	20	30	31	49	70	289	540
	9.4%	3.7%	5.6%	5.7%	9.1%	13.0%	53.5%	100.0%
1996-2015	34	9	6	10	18	35	128	240
	14.2%	3.8%	2.5%	4.2%	7.5%	14.6%	53.3%	100.0%
24 Month Return								
1927-2015	123	25	31	33	48	60	737	1057
	11.6%	2.4%	2.9%	3.1%	4.5%	5.7%	69.7%	100.0%
1971-2015	55	12	10	15	22	28	398	540
	10.2%	2.2%	1.9%	2.8%	4.1%	5.2%	73.7%	100.0%
1996-2015	43	7	4	5	9	7	165	240
	17.9%	2.9%	1.7%	2.1%	3.8%	2.9%	68.8%	100.0%

Insurance Prices from S&P 500 Options 2015-2017 vs. Historic Frequencies Show High Risk Aversion in 1-year Options.

Investors pay up to hedge against stock market, economy falls.



VI. Summary: Risk Aversion Evident in Stock Market Insurance Costs from S&P 500 Options.

- In 2005-2006, Stock market insurance prices implicit in S&P500 options showed little risk aversion, as prices for "right tail" moves (stock prices up 12.5%+) were greater than for insurance against "left tail risks," falls of 12.5%

- From 2008-2017, prices of left tail insurance were higher than for right tail upside bets, presumably reflecting payment for hedges against sharp falls in stock prices and associated poor economies. In extreme times such as the Great Recession, the Sovereign Debt Crisis and the China stock market crash, these price differentials were huge (e.g., 50%-20%=30%).

- Post August 2015 (China stock crash), risk aversion has diminished and prices of left tail risk have dropped. Risk aversion appears higher than 2005/2006, perhaps reflecting memories of the Great Recession and Sov Debt Crisis.

- Insurance prices for falling stock prices are substantially above those for rising stock prices, despite historical frequency distributions opposite.

Appendix: SBCLI for 17 Trillion Dollar Economies 2006-2017

Stocks, Bonds, Consumers Leading Indicators (SBCLI©) *(2Q Returns, Growth)*

Douglas T. Breeden, Duke University and Amundi Asset Management 9/21/2017 22:59

	United St	Canada	Brazil	Mexico	France	Germany	Italy	Spain	United Kingdo	Russia	Turkey	Japan	Australia	South Kor	China	India	Indonesia	United Kingdom
	Americas				*Europe*				*FTSE 100*			*AustralAsia*						*FTSE 250*
2006-Q4	-1.3	-1.2	1.7	2.4	-1.9	0.5	0.8	1.6	-2.1	2.6	-2.3	-0.3	-0.2	-0.8	2.7	1.7	3.6	
2007-Q1	-0.9	-0.8	4.0	3.4	0.4	-0.6	1.5	2.0	-1.0	3.2	-0.7	1.9	3.3	0.0	3.8	2.1	4.3	
2007-Q2	-2.8	0.1	4.4	3.1	0.4	-1.7	0.6	-0.4	-0.3	2.7	0.0	1.0	2.5	0.9	4.2	1.0	3.7	
2007-Q3	-2.9	0.2	3.1	1.5	-1.1	-0.5	-1.6	-1.4	-1.1	2.5	1.0	-1.5	-0.3	2.4	1.8	2.6	4.6	
2007-Q4	-3.1	0.5	3.6	-0.5	-3.5	-3.3	-3.1	-0.8	-2.2	3.0	0.8	-2.6	-0.1	0.8	-0.4	4.7	5.3	
2008-Q1	-4.4	0.8	3.5	-0.8	-7.0	-5.1	-4.1	-2.1	-4.6	1.7	-2.4	-2.7	-4.1	-3.2	-2.5	2.1	3.5	
2008-Q2	-3.4	-1.4	2.0	0.3	-7.0	-5.5	-3.8	-4.4	-5.6	1.3	-4.1	-2.8	-7.3	-4.1	-2.9	-2.0	-0.9	
2008-Q3	-3.7	-2.4	0.9	-1.3	-5.7	-4.8	-4.1	-5.7	-6.6	0.0	-3.5	-2.9	-7.2	-4.4	-1.9	-4.5	-3.4	
2008-Q4	-7.5	-7.4	-4.1	-6.4	-8.5	-7.3	-6.7	-6.7	-10.6	-4.4	-5.7	-5.6	-8.0	-9.2	0.2	-6.0	-6.4	
2009-Q1	-6.3	-6.6	-3.5	-7.7	-5.6	-4.2	-6.6	-5.0	-6.8	-5.4	-4.2	-5.6	-5.6	-4.8	1.1	-6.5	-3.2	
2009-Q2	0.3	3.1	5.7	-1.4	1.4	2.0	-1.3	-2.3	-0.3	1.6	1.2	0.8	2.0	5.0	3.8	0.6	4.2	
2009-Q3	4.5	7.0	7.4	5.3	5.4	3.3	3.5	2.2	3.7	1.7	5.6	3.6	6.0	7.7	4.3	3.9	5.4	
2009-Q4	4.0	4.8	3.7	5.4	5.9	3.1	3.3	3.2	6.2	-0.1	3.7	1.1	4.7	3.8	2.5	1.2	1.5	
2010-Q1	1.4	3.5	1.8	2.3	4.4	2.8	1.0	-0.7	3.3	0.9	1.1	0.8	2.2	1.6	2.1	0.8	-0.6	
2010-Q2	1.2	2.5	0.1	0.7	0.7	1.4	-1.4	-2.7	1.4	-0.4	0.7	0.9	-0.1	0.8	1.5	-0.6	0.0	
2010-Q3	0.6	1.0	0.5	0.7	-0.4	0.6	-0.6	-2.5	0.6	-0.6	0.8	-0.2	-0.6	1.0	0.3	-1.7	-0.6	
2010-Q4	2.7	2.3	2.5	2.4	1.9	1.9	0.9	-1.5	0.4	0.8	1.2	-1.1	0.5	1.8	0.5	-0.1	0.5	
2011-Q1	4.3	2.3	1.6	1.9	3.7	3.8	0.9	-1.8	1.4	1.5	0.0	-1.7	1.3	1.7	0.6	-0.2	0.1	
2011-Q2	1.1	0.0	0.3	0.2	-1.3	0.0	-0.2	-2.0	-0.4	0.3	-1.2	-1.2	-0.3	-0.1	-1.0	-0.7	-0.1	
2011-Q3	-1.4	-1.6	-1.7	1.0	-5.5	-2.9	-3.7	-3.3	-2.4	-1.0	-1.5	0.0	-3.1	-2.8	-2.8	-1.1	1.6	
2011-Q4	-1.3	-1.5	-2.3	0.5	-4.2	-2.9	-6.1	-4.4	-1.5	-1.3	-2.5	-0.3	-4.0	-4.0	-3.5	-2.8	-0.4	
2012-Q1	1.0	-0.1	1.0	1.0	-0.1	0.4	-3.8	-2.3	1.5	-0.4	-1.6	0.1	-1.0	-1.3	-3.1	-2.0	-0.8	
2012-Q2	0.9	-0.7	0.6	1.3	0.7	0.9	-3.2	-3.3	0.6	-0.4	-0.7	0.5	-0.6	-1.1	-2.9	-2.4	1.1	
2012-Q3	-0.9	-1.1	-0.6	1.1	-0.9	-0.2	-2.4	-3.3	-0.4	-1.0	0.2	-1.1	-2.4	-2.0	-2.8	-3.3	1.2	
2012-Q4	0.0	0.5	0.5	1.3	1.7	1.1	0.0	-0.8	1.3	-0.4	1.1	-0.8	-1.0	-0.9	-2.7	-2.1	1.0	
2013-Q1	0.7	0.7	0.2	1.8	1.5	0.9	-0.5	-0.8	1.8	0.2	0.8	3.5	1.2	-1.6	-1.8	-1.4	1.0	
2013-Q2	0.3	0.5	-0.4	-0.2	1.1	0.8	-1.1	-0.8	1.5	-0.7	0.1	6.0	0.6	-2.0	-2.0	-1.6	1.3	
2013-Q3	0.5	0.9	0.3	-1.1	0.9	1.6	-0.2	-0.2	1.5	-0.6	-2.1	1.8	1.2	-0.8	-1.6	-2.7	-0.5	
2013-Q4	1.9	1.2	0.1	0.0	2.0	0.8	1.8	2.1	1.7	0.5	-2.0	-1.0	2.3	0.1	-1.3	-2.4	-1.5	
2014-Q1	2.1	0.9	0.6	-0.4	0.6	0.8	2.4	2.2	1.3	-0.2	-2.4	0.9	1.4	-0.6	-1.2	-2.0	-0.3	
2014-Q2	1.7	1.0	0.4	1.0	-0.2	0.3	1.7	1.0	1.0	-1.1	-0.8	-3.7	0.9	-1.8	-1.4	-1.9	0.4	
2014-Q3	2.9	1.1	0.7	2.1	1.1	-0.9	0.3	0.6	1.8	-0.8	1.4	-4.6	1.0	-1.1	-1.0	-1.0	-0.4	
2014-Q4	3.4	-0.6	0.6	0.2	-0.9	-0.7	-1.1	-0.4	0.2	-1.1	-0.2	1.0	-0.6	-1.4	-0.3	-1.1	-1.3	
2015-Q1	3.0	-2.1	-3.2	-0.4	0.5	1.0	1.2	0.3	0.2	-2.2	-0.4	1.1	-0.2	-1.8	0.2	-1.4	-1.2	
2015-Q2	2.6	-1.0	-4.5	0.8	2.3	1.8	4.1	1.8	2.0	-2.5	-1.1	0.8	1.0	-0.6	1.7	-1.7	-1.0	
2015-Q3	1.6	-0.5	-4.6	0.5	0.0	-1.2	2.4	1.0	-0.1	-4.1	-2.1	-0.6	-0.8	-1.0	-0.3	-2.3	-2.0	
2015-Q4	1.2	-0.9	-5.0	-0.1	-1.1	-1.4	0.5	-0.1	-0.8	-4.5	-1.8	-2.1	-1.2	-0.6	-1.1	-3.0	-1.7	
2016-Q1	0.9	-0.6	-4.5	-0.2	0.1	-1.4	-1.4	-0.6	-0.4	-3.6	-1.4	-3.3	-0.9	-1.5	-0.9	-3.6	-0.1	
2016-Q2	1.9	0.6	-3.4	0.2	0.5	-1.9	-1.4	-0.2	0.6	-2.5	-0.3	-2.9	-0.1	-1.8	-1.0	-3.5	0.6	0.6
2016-Q3	3.3	1.5	-1.5	1.4	-0.8	-0.7	0.3	1.1	2.7	-2.2	0.0	-1.6	0.3	-0.7	-0.4	-2.4	1.2	1.0
2016-Q4	2.3	1.5	-1.4	0.6	0.9	0.6	0.8	1.6	2.9	-2.0	-0.5	-0.1	1.0	-1.0	0.6	-2.6	0.7	1.5
06/23/16	0.4	1.6	-2.7	0.0	-1.0	-0.7	1.3	0.5	-0.4	-2.6	-0.6	-1.1	0.0	-1.3	-0.3	-4.1	-0.5	-0.4
06/27/16	-0.8	0.9	-3.4	-0.7	-2.8	-2.2	-0.6	-1.2	-1.9	-3.3	-1.0	-1.8	-0.7	-1.9	-0.6	-4.5	-0.7	-3.6
11/04/16	0.2	2.1	0.3	0.1	-1.0	-0.3	0.2	0.4	0.8	-2.2	-1.2	-0.5	-0.2	-1.3	0.4	-3.5	0.6	-0.4
Avg Q4 201	2.3	1.5	-1.4	0.6	0.9	0.6	0.8	1.6	2.9	-2.0	-0.5	-0.1	1.0	-1.0	0.6	-2.6	0.7	1.5
12/30/16	3.0	2.3	-1.1	0.2	2.1	1.7	2.1	2.2	3.8	-0.5	-0.4	0.8	1.8	-0.9	0.8	-2.4	0.7	2.2
07/07/17	3.2	3.2	1.5	1.1	1.9	3.2	3.3	2.7	3.2	-1.3	1.9	1.3	1.8	2.1	0.1	-1.2	1.7	2.4
08/24/17	3.1	3.3	3.8	1.5	1.6	2.5	3.7	2.6	3.1	-0.8	3.0	0.9	2.1	2.1	-0.2	-1.2	1.9	2.5
Country	United S	Canada	Brazil	Mexico	France	Germany	Italy	Spain	UK FTSE 10	Russia	Turkey	Japan	Australia	South Ko	China	India	Indonesia	UK FTSE 250

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Breeden was Associate Editor of 5 top journals. He was Founding Editor and Editor for 10 years of the Journal of Fixed Income. He was elected to the Board of Directors of the American Finance Association and in 2010 a lifetime Fellow. The International Association for Quantitative Finance named Breeden "Financial Engineer of the Year 2013" for being an "industry pioneer."

Breeden holds a Ph.D. in Finance from Stanford and an S.B. from M.I.T. He served on the MIT President's Council, the Sloan School Visiting Committee and the Stanford Business School Advisory Council. He was named an Honorary Professor of the Chinese Academy of Sciences and served on the Boards of Goethe Business School in Germany and the Financial Management Association. He is on the Board of Trustees of Commonfund and is a Senior Research Consultant for Amundi Smith Breeden, a money management firm he co-founded.

During his career, Breeden has been active in philanthropy. He provided naming grants for Breeden Hall and the Breeden Professorship at Duke's Fuqua School of Business, the Breeden Conference Room at MIT Sloan, Breeden Theater at Episcopal High School and the Breeden Memorial Library in his hometown of Leavenworth, Indiana.