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Advanced Financial Risk Management:

Tools and Techniques for Integrated Credit Risk, Market Risk, Liquidity Risk and Interest Rate Risk Management

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Part 2: Risk Management Techniques for Interest Rate Analytics

Chapter 3:
Interest rate risk introduction and overview

Interest rate risk is at the heart of all of the silos of truly integrated risk management: credit risk, market risk, asset and liability management ("ALM"), liquidity risk, performance measurement, and even operational risk. Credit risk analysis that is not built on a random interest rate risk framework completely misses one of the key macro-economic factors driving default. This is even more true when credit risk omits explicit modeling of a key macro factor like home prices. Both interest rates and home prices, as predicted by Jarrow et al in the FDIC Loss Distribution Model (December 2003), are critical drivers of correlated bank defaults as the one trillion dollar bail-out of the U.S. savings and loan industry in the 1980s and 1990s and the one trillion dollar bail-out of the U.S. "too big to fail" institutions in 2008 and 2009 confirms. Market risk at most institutions includes a large proportion of fixed income instruments, so we have to deal with interest rate risk in a comprehensive way to deal with market risk. Asset and liability management at most institutions involves both sides of the balance sheet and a range of instruments with complexities that go far beyond those found in market risk, such as pension liabilities, insurance policies, non-maturity deposits, credit card advances, and so on. Analysis of each of these instruments must be based on a random interest rate framework as well. In ALM, the complexity of the task is aggravated by the frequent need to do the analysis both on a mark to market basis and on a net income simulation basis looking forward. Liquidity risk analysis, which is focused on how cash flows respond to changes in macro factors and their impact on credit risk, market risk and ALM risk, is a "derivative" risk in the sense that it stems from some other problem.

For all of these reasons, we pay special attention to interest rate risk in this book. In this chapter, we focus on the big picture. In particular, we focus on two key questions:

1. How have interest rates behaved in the past?
2. Is there an optimal interest rate risk position for a financial institution and, if so, what are the determinants of what that position should be?

We start by focusing on the first question, because we want our analysis of interest rate risk to be grounded in reality. Too often, analysts of interest rate risk assuming a yield curve smoothing method or a model of interest rate movements that are simply inconsistent with market prices of fixed income instruments and with historical (and with high probability) and future movements in interest rates. We begin this chapter by summarizing key facts from the 50 year history of movements in the U.S. Treasury yield curve. We select this data set for a simple reason-the sheer size of the data and length of the time period for which data is available.

Background Information on Movements in the U.S. Treasury Yield Curve

Space does not permit a detailed, day by day analysis of the movements of the U.S. Treasury yield curve, but these references provide exactly such an analysis and we strongly encourage the serious reader to review them:

> Dickler, Daniel T., Robert A. Jarrow and Donald R. van Deventer, "Inside the Kamakura Book of Yields: A Pictorial History of 50 Years of U.S. Treasury Forward Rates," Kamakura Corporation memorandum, September 13, 2011.
>
> Dickler, Daniel T. and Donald R. van Deventer, "Inside the Kamakura Book of Yields: An Analysis of 50 Years of Daily U.S. Treasury Forward Rates," Kamakura blog, www.kamakuraco.com, September 14, 2011.
>
> Dickler, Daniel T., Robert A. Jarrow and Donald R. van Deventer, "Inside the Kamakura Book of Yields: A Pictorial History of 50 Years of U.S. Treasury Zero Coupon Bond Yields," Kamakura Corporation memorandum, September 26, 2011.
>
> Dickler, Daniel T. and Donald R. van Deventer, "Inside the Kamakura Book of Yields: An Analysis of 50 Years of Daily U.S. Treasury Zero Coupon Bond Yields," Kamakura blog, www.kamakuraco.com, September 26, 2011.
>
> Dickler, Daniel T., Robert A. Jarrow and Donald R. van Deventer, "Inside the Kamakura Book of Yields: A Pictorial History of 50 Years of U.S. Treasury Par Coupon Bond Yields," Kamakura Corporation memorandum, October 5, 2011.
>
> Dickler, Daniel T. and Donald R. van Deventer, "Inside the Kamakura Book of Yields: An Analysis of 50 Years of Daily U.S. Par Coupon Bond Yields," Kamakura blog, www.kamakuraco.com, October 6, 2011.

This publications are either available on the Kamakura Corporation website www.kamakuraco.com or available by request from info@kamakuraco.com. The Kamakura Corporation also includes three videos which show movements in interest rates on a daily basis from January 2, 1962 to August 22, 2011. We encourage readers to review the following narrated videos as well:

Figure 1

Interest Rate Risk Video: 50 Years of Par Coupon Bond Yields, narrated by Dr. Donald R. van Deventer, founder of Kamakura Corporation

Interest Rate Risk Video: 50 Years of Zero Coupon Bond Yields, narrated by Dr. Donald R. van Deventer, founder of Kamakura Corporation

Interest Rate Risk Video: 50 Years of Forward Rate Movements, narrated by Dr. Donald R. van Deventer, founder of Kamakura Corporation

The series of pictorial volumes and analysis by Dickler, Jarrow and van Deventer make a number of facts clear about the historical movements of interest rates in the U.S. Treasury market, one of the largest fixed income markets in the world. A reader who is thinking, “But my market is different” is guilty of risk fallacy number 1 that we discussed in the Introduction: “If it hasn’t happened to me yet, it won’t happen to me, even if it’s happened to someone else.” This is the same mistake made by American risk managers who thought that home prices wouldn’t fall like they did in Japan. It is the same mistake made by American ALM experts who thought that the low interest rates in the wake of the collapse of the Japanese bubble would never happen anywhere else. Ideally, this book would analyze interest rates in 20 countries, not one, but space does not permit that.

Here is a list of the key facts that the Dickler, Jarrow and van Deventer studies identified about the U.S. Treasury market experience.

Fact 1: Historical data is typically available at maturities that vary over time, as seen in this table of the 12,395 data points of daily data on U.S. Treasury yields from January 2, 1962 to August 22, 2011:

Figure 2

Analysis of Federal Reserve H15 Release Data Regimes

Start Date	End Date	Data Regime	Number of Observations
1/2/1962	6/30/1969	1, 3, 5 and 10 years	1,870
7/1/1969	5/28/1976	1, 3, 5, 7 and 10 years	1,722
6/1/1976	2/14/1977	1, 2, 3, 5, 7 and 10 years	178
2/15/1977	12/31/1981	1, 2, 3, 5, 7, 10 and 30 years	1,213
1/4/1982	9/30/1993	3 and 6 months with 1, 2, 3, 5, 7, 10 and 30 years	2,935
10/1/1993	7/30/2001	3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	1,960
7/31/2001	2/15/2002	1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	135
2/19/2002	2/8/2006	1, 3 and 6 months with 1, 2, 3, 5, 7, 10, and 20 years	994
2/9/2006	8/22/2011	Second era: 1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	1,388
		Total	12,395

Fact 2: It is very rare for the forward rate curve to be monotonically upward sloping or downward sloping. We discuss the derivation of forward rate curves in the following chapters. This chart shows the distribution of the forward curves among three types of shapes: humped, upward sloping or downward sloping:

Figure 3

Kamakura Corporation
U.S. Treasury Monthly Forward Rates, January 2, 1962 to August 22, 2011
Number of Forward Rate Curve Shapes by Data Regime

				Forward Curve Shape		
Start Date	End Date	Data Regime	Number of Observations	Humped	Monotonically Downward Sloping	Monotonically Upward Sloping
1/2/1962	6/30/1969	1, 3, 5 and 10 years	1,870	1,503	40	327
7/1/1969	5/28/1976	1, 3, 5, 7 and 10 years	1,722	1,707	11	4
6/1/1976	2/14/1977	1, 2, 3, 5, 7 and 10 years	178	146		32
2/15/1977	12/31/1981	1, 2, 3, 5, 7, 10 and 30 years	1,213	1,163	15	35
1/4/1982	9/30/1993	3 and 6 months with 1, 2, 3, 5, 7, 10 and 30 years	2,935	2,930		5
10/1/1993	7/30/2001	3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	1,960	1,960		
7/31/2001	2/15/2002	1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	135	135		
2/19/2002	2/8/2006	1, 3 and 6 months with 1, 2, 3, 5, 7, 10, and 20 years	994	669		325
2/9/2006	8/22/2011	Second era: 1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	1,388	1,354		34
		Total	12,395	11,567	66	762

In percentage terms, the forward rate curve has been humped for 93.32% of the observations since 1962:

Figure 4

Kamakura Corporation
U.S. Treasury Monthly Forward Rates, January 2, 1962 to August 22, 2011
Number of Forward Rate Curve Shapes by Data Regime

				Probability of Forward Curve Shape		
Start Date	End Date	Data Regime	Number of Observations	Humped	Monotonically Downward Sloping	Monotonically Upward Sloping
1/2/1962	6/30/1969	1, 3, 5 and 10 years	1,870	80.37%	2.14%	17.49%
7/1/1969	5/28/1976	1, 3, 5, 7 and 10 years	1,722	99.13%	0.64%	0.23%
6/1/1976	2/14/1977	1, 2, 3, 5, 7 and 10 years	178	82.02%	0.00%	17.98%
2/15/1977	12/31/1981	1, 2, 3, 5, 7, 10 and 30 years	1,213	95.88%	1.24%	2.89%
1/4/1982	9/30/1993	3 and 6 months with 1, 2, 3, 5, 7, 10 and 30 years	2,935	99.83%	0.00%	0.17%
10/1/1993	7/30/2001	3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	1,960	100.00%	0.00%	0.00%
7/31/2001	2/15/2002	1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	135	100.00%	0.00%	0.00%
2/19/2002	2/8/2006	1, 3 and 6 months with 1, 2, 3, 5, 7, 10, and 20 years	994	67.30%	0.00%	32.70%
2/9/2006	8/22/2011	Second era: 1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	1,388	97.55%	0.00%	2.45%
		Total	12,395	93.32%	0.53%	6.15%

Fact 3: It is very common for the forward rate curve to show a large number of local maximums and local minimums. Figure 5 summarizes the breakdown of the number of local minimums and maximums ("humps") over the 12,395 business days in the data set:

Figure 5

Kamakura Corporation
U.S. Treasury Monthly Forward Rates, January 2, 1962 to August 22, 2011
Number of Local Maximums and Minimums by Data Regime

	Number of Local Maximums and Minimums										
Data Regime	0	1	2	3	4	5	6	7	8	9	Total
1, 3, 5 and 10 years	367	579	924								1,870
1, 3, 5, 7 and 10 years	15	475	572	660							1,722
1, 2, 3, 5, 7 and 10 years	32	29	25	55	37						178
1, 2, 3, 5, 7, 10 and 30 years	50	77	291	202	440	153					1,213
3 and 6 months with 1, 2, 3, 5, 7, 10 and 30 years	5	25	173	343	1,042	671	427	249			2,935
3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years		25	10	237	96	788	217	580	7		1,960
1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years			1	48	80	5	1				135
1, 3 and 6 months with 1, 2, 3, 5, 7, 10, and 20 years	325	59	206	96	120	7	116	65			994
Second era: 1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	34	167	110	500	88	177	44	197	61	10	1,388
Total	828	1,436	2,312	2,141	1,903	1,801	805	1,091	68	10	12,395

	Probability of Local Maximums and Minimums										
Data Regime	0	1	2	3	4	5	6	7	8	9	Total
1, 3, 5 and 10 years	19.6%	31.0%	49.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
1, 3, 5, 7 and 10 years	0.9%	27.6%	33.2%	38.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
1, 2, 3, 5, 7 and 10 years	18.0%	16.3%	14.0%	30.9%	20.8%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
1, 2, 3, 5, 7, 10 and 30 years	4.1%	6.3%	24.0%	16.7%	36.3%	12.6%	0.0%	0.0%	0.0%	0.0%	100.0%
3 and 6 months with 1, 2, 3, 5, 7, 10 and 30 years	0.2%	0.9%	5.9%	11.7%	35.5%	22.9%	14.5%	8.5%	0.0%	0.0%	100.0%
3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	0.0%	1.3%	0.5%	12.1%	4.9%	40.2%	11.1%	29.6%	0.4%	0.0%	100.0%
1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	0.0%	0.0%	0.7%	35.6%	59.3%	3.7%	0.7%	0.0%	0.0%	0.0%	100.0%
1, 3 and 6 months with 1, 2, 3, 5, 7, 10, and 20 years	32.7%	5.9%	20.7%	9.7%	12.1%	0.7%	11.7%	6.5%	0.0%	0.0%	100.0%
Second era: 1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	2.4%	12.0%	7.9%	36.0%	6.3%	12.8%	3.2%	14.2%	4.4%	0.7%	100.0%
Total	6.7%	11.6%	18.7%	17.3%	15.4%	14.5%	6.5%	8.8%	0.5%	0.1%	100.0%

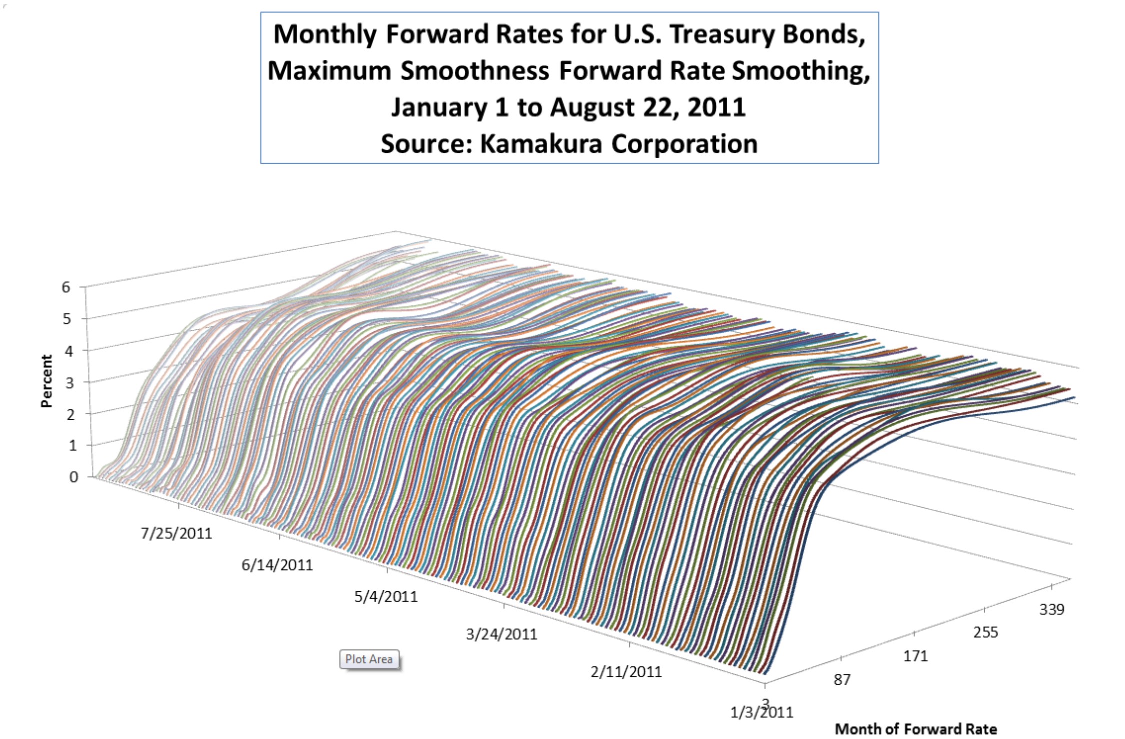
In percentage terms, an interest rate modeler who wants to be able to replicate the shape of the forward rate curve correctly at least 90% of the time needs a model which can create at least 6 local maximums or minimums:

Figure 6

	Cumulative Probability of Local Maximums and Minimums									
Data Regime	0	1	2	3	4	5	6	7	8	9
1, 3, 5 and 10 years	19.6%	50.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1, 3, 5, 7 and 10 years	0.9%	28.5%	61.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1, 2, 3, 5, 7 and 10 years	18.0%	34.3%	48.3%	79.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1, 2, 3, 5, 7, 10 and 30 years	4.1%	10.5%	34.5%	51.1%	87.4%	100.0%	100.0%	100.0%	100.0%	100.0%
3 and 6 months with 1, 2, 3, 5, 7, 10 and 30 years	0.2%	1.0%	6.9%	18.6%	54.1%	77.0%	91.5%	100.0%	100.0%	100.0%
3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	0.0%	1.3%	1.8%	13.9%	18.8%	59.0%	70.1%	99.6%	100.0%	100.0%
1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	0.0%	0.0%	0.7%	36.3%	95.6%	99.3%	100.0%	100.0%	100.0%	100.0%
1, 3 and 6 months with 1, 2, 3, 5, 7, 10, and 20 years	32.7%	38.6%	59.4%	69.0%	81.1%	81.8%	93.5%	100.0%	100.0%	100.0%
Second era: 1, 3 and 6 months with 1, 2, 3, 5, 7, 10, 20 and 30 years	2.4%	14.5%	22.4%	58.4%	64.8%	77.5%	80.7%	94.9%	99.3%	100.0%
Total	6.7%	18.3%	36.9%	54.2%	69.5%	84.1%	90.6%	99.4%	99.9%	100.0%

Fact 4: During some extended periods of time, the forward rate curve may have no or few humps. 2011 was such a year, as shown in this figure:

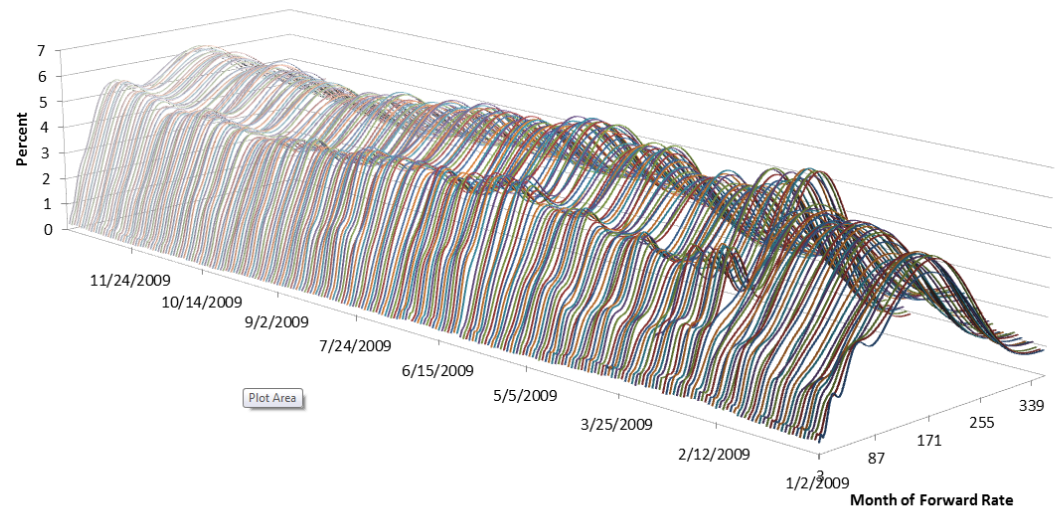
Figure 7



Fact 5: It is equally true that extended periods of extreme humps can prevail, such as the forward rate curves for 2009 in the aftermath of Federal Reserve efforts to speed recovery from the 2008 collapse of firms like Bear Stearns, Lehman Brothers, FHLMC, FNMA, AIG, Wachovia and Washington Mutual:

Figure 8

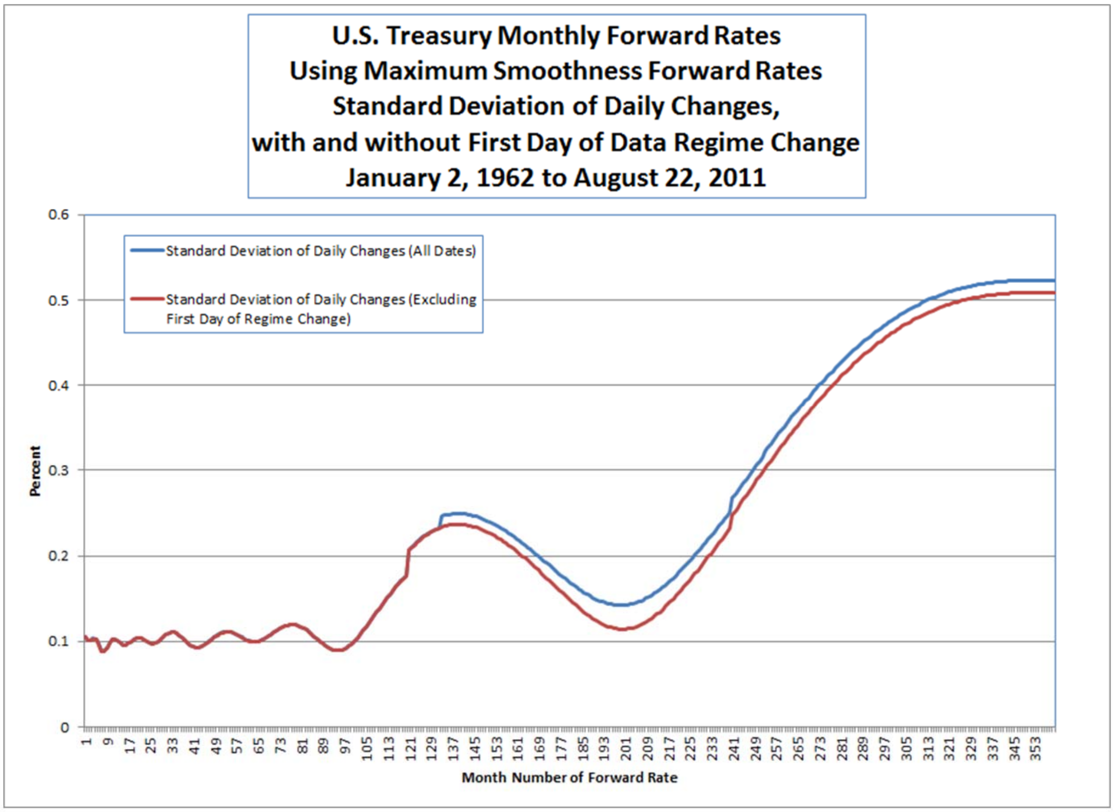
Monthly Forward Rates for U.S. Treasury Bonds, Maximum Smoothness Forward Rate Smoothing, January 1 to December 31, 2009
Source: Kamakura Corporation



Dickler, Jarrow and van Deventer find that the most frequent local minimums or maximums are at months 5, 10, 22, 34, 58, 79, 113, 144, 202. These optima are close to knot points (data at which the Federal Reserve provides data) at 6, 12, 24, 36, 60, 84, 120, and 240 months.

Fact 6: The volatility of the daily changes in forward rates can be calculated both using all data and using all data except the first day after the Federal Reserve changes the “data regime,” the maturities at which U.S. Treasury yields are made available. The volatilities of daily changes do not have a simple upward sloping, downward sloping or constant pattern. In fact, an assumption that volatilities have a simple shape is dramatically wrong, as shown in this figure:

Figure 9

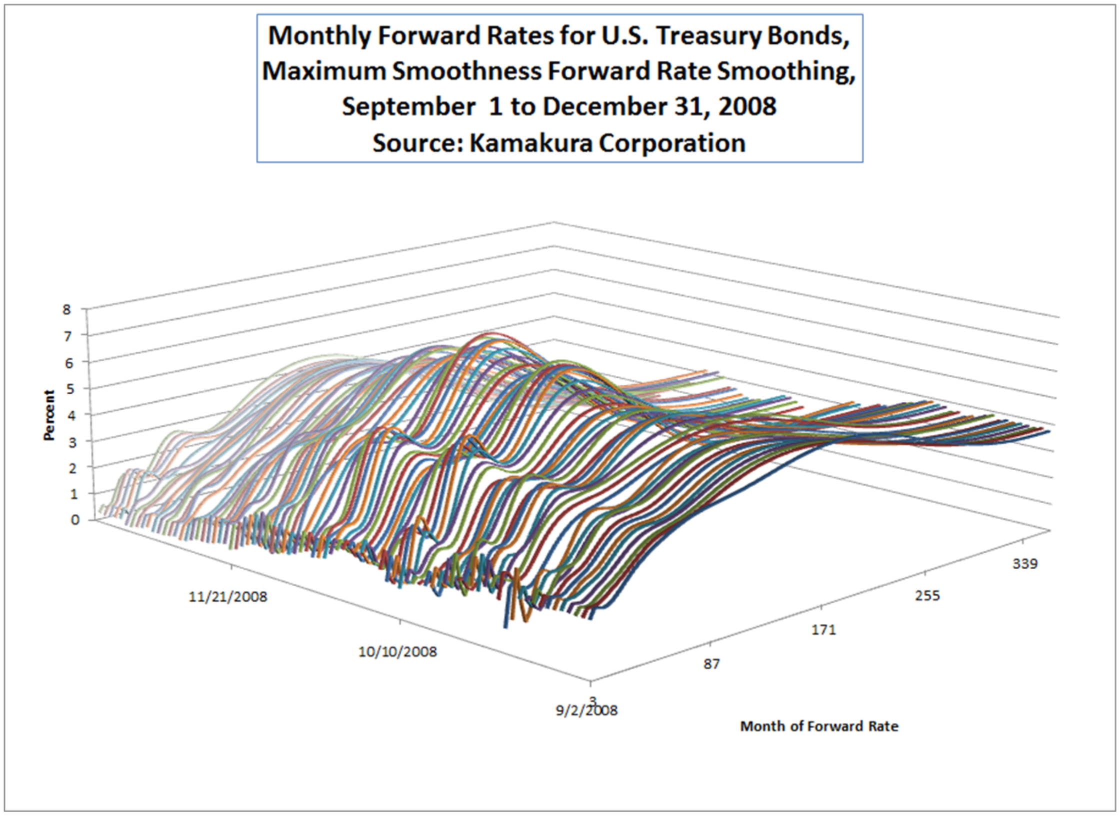


Fact 7: Dickler, Jarrow and van Deventer find that the smoothing techniques employed in the figures above and explained in later chapters produce very smooth forward rate curves. Adams and van Deventer (1994) adopt a common definition of smoothness used in engineering and computer graphics, the integral of the squared second derivative of the forward rate over the length of the forward rate curve. We can approximate this by taking the sum of the squared second differences of the (up to) 360 monthly forward rates on each of the 12,395 business days in the data set.

$$Z[t] = \sum_{i=2}^{360} \left[(f(i) - f(i-1)) - (f(i-1)) - f(i-2)) \right]^2$$

The lowest values of Z[t] are those days with the smoothest forward rate curves. The highest values of Z[t] are those days on which the forward rate curve is least smooth. Not surprisingly, Dickler, Jarrow and van Deventer find that the least smooth forward rate curve comes about on September 17, 2008, two days after the formal filing of bankruptcy by Lehman Brothers. The Federal Reserve's efforts to provide liquidity via the Treasury market and direct lending result in dramatic variation of the forward rate curve. This volatility was inevitable because of the short term rates reported by the Federal Reserve on its H15 statistical release for September 17, 2008: which is inevitable because of inputs from the Federal Reserve H15 statistical release on that day: 3 months=0.03%, 6 months=1.03%, and 1 year=1.50%. The figure below shows how the Fed's attempts to supply liquidity caused dramatic movements in the forward rate curve. Note that, due to limitations in the graphics routine used, forward rates are plotted for every third month:

Figure 10



Fact 8: Nominal interest rates can indeed turn negative. This is not obvious in the Federal Reserve's H15 data for a simple reason: the Federal Reserve has acknowledged that it will not publish negative interest rates because the U.S. Treasury "will not issue" bonds with a negative coupon. Academics have argued that nominal interest rates cannot be negative "because it is costless to store cash." In fact, it is NOT costless to store cash and the proof of that is the August 5, 2011 announcement by the Bank of New York Mellon that it would charge a fee to clients who supplied zero interest demand deposits to the bank with balances of more than $50 million. The Wall Street Journal report on the fee noted that one month U.S. Treasury bill rates were trading at negative yields on that day. Negative nominal rates have been reported on the web site of the Hong Kong Monetary Authority and observed in Switzerland and Japan as well.

With this data as background, we now turn to the mechanics of how a financial institution can and should manage interest rate risk.

A Step by Step Approach to Analyzing Interest Rate Risk

Besides reviewing historical experience, our goal in this chapter is to address the big picture of determining the optimal degree of interest rate risk for a major financial institution. We start with a very fundamental question: **What Number is Interest Rate Risk Management All About?**

In Chapter 1, we noted how Robert Merton and Robert Jarrow have both proposed that a properly described "put option" is the single number which best describes the total risk of a financial institution in most situations. If we are thinking only about the firm's current portfolio, this put option is a European put option exercised only on one specific date on the value of the portfolio we hold now. If we are thinking about a multi-period analysis of the firm's balance sheet going forward, this put option can be an American put option exercisable at many dates in the future.

We can describe almost all common risk management risk measures using the Merton and Jarrow analysis of the put option. When one thinks about it, the put option is a much more precise summary of the risk than other terms which are more commonly used to describe risk.

For example

- Instead of the 10 day **value at risk** of a trading portfolio, what is the value of a 10 day put on the firm's current portfolio with an exercise price equal to the portfolio's current market value? The price of the put will increase sharply with the risk of the firm's portfolio, and the put's price will reflect all possible losses and their probability, not just the 99th percentile loss as is traditional in value at risk analysis
- Instead of **stress testing the 12-month net income** of the financial institution to see if net income will go below \$100 million for the year, what is the price of a put option in month 12 which will produce a gain in net income exactly equal to the short-fall of net income versus the \$100 million target? The more interest rate risk in the balance sheet of the financial institution, the more expensive this put will be. The put will reflect all levels of net income shortfall and their probability, not just the shortfalls detected by specific stress tests
- Instead of the **Basel II or Basel III risk-weighted capital ratio** for the bank, what is the price of the put option that insures solvency of the bank in one year's time? This put option measures all potential losses embedded in the financial institution's balance sheet and their probability of occurrence, including both interest rate risk and credit risk, as we discuss at the end of this chapter.
- Instead of **"expected losses" on a collateralized debt obligation tranche's B tranche**, what is the price of a put option on the value of the tranche at par at maturity? This put option reflects all losses on the tranche, not just the average loss, along with their probability of occurrence.
- Instead of **"expected losses on the Bank Insurance Fund"** in the United States, the Federal Deposit Insurance Corporation has valued the put option of retail bank deposits at their par value as discussed in the FDIC's loss distribution model announced on December 10, 2003.

The market values of put options on bank total risk are visible in the market place. Figure 11 shows put option prices at the close of trading on April 20, 2011 for JPMorgan Chase. The closing stock price for JPMorgan Chase was \$42.72

Figure 11

Put Options							Expire at close Friday, April 20, 2012
Strike	Symbol	Last	Chg	Bid	Ask	Vol	Open Int
16.00	JPM120421P00016000	0.02	0.00	N/A	0.01	32	550
17.00	JPM120421P00017000	0.11	0.00	N/A	0.01	12	12
19.00	JPM120421P00019000	0.04	0.00	N/A	0.02	16	150
20.00	JPM120421P00020000	0.04	0.00	N/A	0.02	1	44
21.00	JPM120421P00021000	0.01	0.00	N/A	0.01	43	228
22.00	JPM120421P00022000	0.01	0.00	N/A	0.01	39	480
23.00	JPM120421P00023000	0.12	0.00	N/A	0.01	10	192
24.00	JPM120421P00024000	0.01	0.00	N/A	0.01	9	492
25.00	JPM120421P00025000	0.01	0.00	N/A	0.01	300	1,056
26.00	JPM120421P00026000	0.02	0.00	N/A	0.01	50	824
27.00	JPM120421P00027000	0.02	0.00	N/A	0.01	4	1,003
28.00	JPM120421P00028000	0.02	0.00	N/A	0.01	10	586
29.00	JPM120421P00029000	0.02	0.00	N/A	0.01	200	1,565
30.00	JPM120421P00030000	0.01	0.00	N/A	0.01	50	4,350
31.00	JPM120421P00031000	0.01	0.00	N/A	0.01	30	5,168
32.00	JPM120421P00032000	0.01	0.00	N/A	0.01	10	8,501
33.00	JPM120421P00033000	0.01	0.00	N/A	0.01	30	7,815
34.00	JPM120421P00034000	0.01	0.00	N/A	0.01	2	2,952
35.00	JPM120421P00035000	0.01	0.00	N/A	0.01	15	7,076
36.00	JPM120421P00036000	0.01	↓0.01	N/A	0.01	1	6,777
37.00	JPM120421P00037000	0.02	0.00	N/A	0.01	5	7,908
38.00	JPM120421P00038000	0.01	0.00	N/A	0.01	5	6,988
39.00	JPM120421P00039000	0.01	0.00	N/A	0.01	19	5,668
40.00	JPM120421P00040000	0.01	0.00	N/A	0.01	41	14,092
41.00	JPM120421P00041000	0.01	0.00	N/A	0.01	36	11,037
42.00	JPM120421P00042000	0.01	↓0.02	N/A	0.01	227	14,403
43.00	JPM120421P00043000	0.28	↑0.13	0.27	0.28	16,389	16,449
44.00	JPM120421P00044000	1.28	↑0.43	1.24	1.28	5,099	9,690
45.00	JPM120421P00045000	2.27	↑0.54	2.23	2.28	1,734	7,459
46.00	JPM120421P00046000	3.10	↑0.32	3.20	3.30	78	4,673
47.00	JPM120421P00047000	4.04	↑0.01	4.20	4.30	36	1,312
48.00	JPM120421P00048000	4.50	↓0.28	5.20	5.30	68	417
49.00	JPM120421P00049000	6.15	↑0.10	6.20	6.30	1	104
50.00	JPM120421P00050000	6.95	↑0.05	7.20	7.30	100	251
55.00	JPM120421P00055000	12.05	0.00	12.15	12.30	5	410
60.00	JPM120421P00060000	16.10	0.00	15.30	17.35	10	10

Highlighted options are in-the-money.

With this key Merton-Jarrow insight in mind, a lot of the debate about the proper focus of interest rate risk management fades away. Three different dimensions of a financial institution's risk have dominated past arguments about how much interest rate risk is the right amount:

- **Net interest income (or net income),** a measure which by definition is multi-period in nature and includes instruments that the financial institution owns today and those that it will own in the future. Net interest income as the focus of risk analysis is unheard of on the trading floor but is much discussed by senior management of many financial institutions. Many of the required outputs of the Federal Reserve's "Comprehensive Capital Analysis and Review 2012" stress tests are surprisingly expressed in net income terms.
- **Market value of portfolio equity**, which is "bank speak" for the market value of the assets a financial institution owns today, less the market value of its liabilities. This is the common trading floor choice, aided by the luxury of having market prices for almost every asset and liability in full view. It is also increasing popular among sophisticated total balance sheet risk managers even when the balance sheet is dominated by assets and liabilities with no observable market price.
- **Market-based equity ratio**, which is the ratio of the mark to market value of the equity of the portfolio ("market value of portfolio equity" in bank speak) divided by the market value of assets. This is most closely related to the capital ratio formulas of the primary capital era, Basel I, Basel II, Basel III, and Solvency II.
- **Default probability of the institution**, which is another strong candidate as a single measure of risk. The complexity here is over which time period the default probability should be for.

While these measures can move in conflicting directions under specific scenarios, the put option proposed by Merton and Jarrow behaves in a consistent way, which is why Professor Jarrow labels the put option a "coherent risk measure" as noted in Chapter 1.

The Interest Rate Risk Safety Zone

The complex interaction between interest rate risk and credit risk shouldn't be allowed to obscure a key conclusion about interest rate risk. Assuming away the potential default of the assets that a financial institution may hold,

> ***No matter which maturity of investment we make with the capital of the financial institution, this firm will never go bankrupt from interest rate risk as long as the remaining assets are financed on a matched maturity basis. This firm is in the "safety zone" and shareholders are indifferent to the choice of maturity on the investment of these equity funds. The reason they are indifferent is because, even at the retail investor level, the investor can form a model portfolio with the investor's desired risk. For example, what if management invested the equity in 10 year bonds and the retail investor wanted the funds invested in a one year maturity. The investor achieves that by buying x% of the firm's common stock, selling short x% of the 10 year bonds[1], and buying x% of the one year bonds.***

Once the firm begins to mismatch on the loan funding, the probability of bankruptcy creeps up from zero. For any mismatch, there is an interest rate scenario (often an incredibly unlikely but theoretically possible scenario) which can cause bankruptcy. Once this bankruptcy probability becomes significant from a practical point of view, shareholders begin to bear the expected cost of bankruptcy, which is the unhedgable loss of the perpetual ability of the financial institution to generate profitable assets that

[1] More practically, the investor would short government bond futures.

earn an excess above the return on traded securities of equivalent risk available in the market. It is this expected bankruptcy loss which causes the firm's stock price to decline when the firm moves out of the safety zone. As long as the firm is within the safety zone, the firm's stock price will always be indifferent[2] to the level of interest rate risk, all other things being equal, because the interest rate risk is hedgable even by retail investors for their own account.[3]

As we plunge into the interest rate analytics first and then credit risk analytics second, we should not lose sight of this simple truth about interest rate risk.

[2] This doesn't mean that the firm's stock price won't decline if Firm A has taken more risk than Firm B. It means only that Firm A and Firm B, all other things being equal, will have the same initial stock prices if both differ only in the degree of interest rate risk taken in the safety zone.

[3] Lot sizes for financial futures are so small that the argument that this hedging can be done at the retail level is a practical one. At the institutional investor level, of course, this hedging could be much easier.