Interest Rate Structure and the Credit Risk of Swaps

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As the market for swaps grows and matures, understanding and measuring the accompanying credit risk remains a concern of bankers, regulators, and corporate users. Swaps have grown explosively in the last decade. At the end of 1982, the aggregate of contracts outstanding was $5 billion. By the end of 1991, contracts outstanding exceeded $4.6 trillion.

In the most general terms, a swap is an agreement between two parties to exchange interest payments for a period of time. While there are many different kinds of swap contracts, they fall into two general categories, interest rate and currency swaps. Interest rate swaps account for most of swap volume, exceeding $3 trillion in 1991.

The first and most popular use of swaps is to transform fixed-rate debt into floating-rate debt, and vice versa. While this can be accomplished with the help of other instruments, such as forward contracts and financial futures and options, swaps offer advantages in the form of greater flexibility and longer maturity, often extending to as long as 10 years. The birth of swaps in the early 1980s can be traced to the financial turbulence at that time and the resulting high volatility of interest rates. High volatility led many borrowers to value more than ever the stability and security of fixed-rate debt, at a time when the capital markets offered it only at an increasingly high premium. This spurred a variety of financial innovations, of which the interest-rate swap was, perhaps, the most important.

When the swap market was in its infancy, firms had to find counterparties with matching needs. Now this is not necessary, because many commercial and investment banks make markets in swaps. This activity allows them to earn income but also exposes these banks to credit risk, that is, the risk of nonperformance by the counterparty. Credit risk of swaps remains a concern and fuels continuing debates about the best ways to measure and price it, and about the appropriate amount of capital that should be set aside to cover possible losses.

One popular method of analyzing the credit risk of swaps is based on Monte Carlo simulations of the future course of interest rates. The use of simulations in this context was popularized by a Bank of England study, which formed the basis for the development of capital requirements for swaps under the Basle Accord. That study, and those that followed it (ISDA 1987; Simons 1989) shared the same basic simulation methodology, estimating the credit exposure on matched pairs of swaps under thousands of hypothetical interest rate scenarios. This study builds on the previous work by incorporating into these hypothetical scenarios an interest rate forecast implicit in the prevailing interest rate structure. It finds that if interest rates are expected to rise in the future, the credit risk of swaps is greater.

Section I of this article begins with a brief history of the swap market, discusses the mechanics of a "plain vanilla" interest rate swap, and describes how changes in interest rates give rise to credit risk. Section II discusses the theories of the term structure of interest rates and calculates the future interest rates implied by a rising term structure. Section III describes the Monte Carlo simulations of hypothetical interest rate scenarios and how they can be used to estimate the potential credit risk of swaps. Section IV incorporates the implicit interest rate forecast into the model and compares the swap credit risk that arises under the flat interest rate structure to the risk implied by rising future rates. The study finds that rising future interest rates result in higher credit risk than flat interest rates. The article concludes with a discussion of the capital requirements for swaps recently implemented by bank regulators and the various modifications to the plain vanilla swap that have been developed in the market to limit credit risk of swaps.

Table 1
Interest Rate Swaps: Outstanding Notional Principal as of December 31, 1991

Currency	U.S. Dollar Equivalent (Millions)	End User (Percent)	Dealer (Percent)	Rank
U.S. Dollar	1,505,995	55.2	44.8	1
Japanese Yen	478,923	44.7	55.3	2
Deutsche Mark	263,411	57.8	42.2	3
British Sterling	253,516	58.1	41.9	4
Swiss Franc	137,620	53.0	47.0	5
French Franc	115,607	85.7	14.3	6
European Currency Unit	72,822	58.4	41.6	7
Australian Dollar	72,339	76.9	23.1	8
Canadian Dollar	61,335	67.3	32.7	9
Italian Lira	34,321	60.2	39.8	10
Dutch Guilder	18,742	44.2	55.8	11
Swedish Krona	18,233	84.0	16.0	12
Other Currencies	17,550	68.1	31.9	13
Belgian Franc	7,523	76.5	23.5	14
New Zealand Dollar	3,399	81.4	18.6	15
Hong Kong Dollar	2,821	56.5	43.5	16
Danish Krone	908	63.1	36.9	17
Total	3,065,065	56.2	43.8	

Source: International Swap Dealers Association, Market Survey, supplied by International Swap Dealers Association.

I. A "Plain Vanilla" Swap

The simplest and most common type of swap, the plain vanilla swap, consists of an exchange between two counterparties of fixed-rate interest for floating-rate interest in the same currency. The principal amount upon which these interest payments are based, called "notional principal," is not exchanged.

Table 1 shows the 1991 dollar equivalent of the total notional principal of interest rate swap contracts. The U.S. dollar is by far the most popular currency, accounting for $1.5 trillion of the $3 trillion interest-rate swap market. While a few swaps had been arranged in the United States in the late 1970s, the first major domestic interest rate swap is usually credited to a 1982 transaction between the Student Loan Marketing Association (Sally Mae) and IT&T Financial Corporation (Wishon and Chevalier 1985). Sallie Mae had issued $100 million of intermediate-term fixed-rate debt, while IT&T had more than $100 million in commercial paper outstanding, which it was rolling over every 90 days. Sallie Mae and IT&T entered into an interest rate swap, exchanging interest payments on $100 million, with Sallie Mae paying IT&T floating-rate and IT&T paying Sallie Mae fixed-rate in return. This gave both companies a better match with their assets, because Sallie Mae had a portfolio consisting mostly of floating-rate assets, while IT&T had a portfolio consisting mostly of fixed-rate assets.

Sallie Mae and IT&T could have simply issued debt that matched their assets, but both companies found that the swap reduced their cost of funds. Sallie Mae, as a government-chartered entity whose debt enjoys an implied government guarantee, could obtain long-term funding at a lower interest rate than

IT&T. At the same time, for short-term funding, Sallie Mae's advantage over IT&T was negligible. Thus, Sallie Mae's comparative advantage in the long-term market meant that the two companies could profitably trade, or swap, their interest payments, and both could save on borrowing costs. The transaction attracted considerable attention and was widely imitated, because the comparative advantage of higher-rated borrowers over lower-rated borrowers in the long-term market turned out to be an almost universal phenomenon.

To look at this comparative advantage in more detail, consider a hypothetical swap transaction between a commercial bank (Bank A) and a manufacturing firm (Company B). Bank A is a highly rated institution that can obtain fixed-rate debt at a relatively low rate but prefers floating-rate debt to match the short-term assets in its portfolio. Company B, on the other hand, has a low credit rating and wants to obtain fixed-rate funding. Table 2 illustrates what their borrowing costs might be without the swap.

Because of its higher rating, Bank A can obtain funding more cheaply than Company B in either market, but it has a comparative advantage in the fixed-rate market. It can borrow at a fixed rate at 1.5 percent less than the fixed rate available to Company B, while in the floating-rate market its advantage is only 0.5 percent.

Both parties can realize savings from an interest rate swap. As illustrated in Figure 1, Bank A can borrow at a fixed rate of 7 percent, while Company B can borrow at a variable rate of LIBOR (London Interbank Offer Rate) + 0.5 percent. In a swap, the bank might pay the company LIBOR − 0.5 percent, while the company pays the bank 7 percent fixed interest, which would exactly cover the bank's expense on its fixed-rate borrowing.

In this example, the "gains from trade" made possible by the swap are shared equally by the two counterparties. The bank's overall interest rate with the swap is LIBOR − 0.5 percent, compared to LIBOR without the swap. Company B's overall borrowing cost is 8 percent (7 percent plus 1 percent, which is the difference between LIBOR + 0.5 percent and LIBOR − 0.5 percent), compared to 8.5 percent without the swap. Each counterparty has saved one-half of 1 percent in borrowing costs through the swap.

Credit market arbitrage such as described above is no longer the only use of swaps. Swaps are frequently employed by financial institutions for the management of interest rate risk. Large banks also act as intermediaries in matched transactions. In this case, the bank arranges swaps with two parties simultaneously, acting as the fixed-rate payer in one contract and the floating-rate payer in the other. In practice, most intermediaries now act as market-makers, entering into an agreement with one party in anticipation of locating a matching counterparty, and earning income from a bid-ask spread. Thus, it is no longer necessary for a prospective swap user to search for a counterparty with complementary needs. One need only call a swap dealer to obtain a price quote for a swap of desired maturity. The market for plain vanilla swaps is standardized and highly competitive, so that price quotes from various dealers are likely to be very similar.

Table 2
Comparison of Borrowing Costs without a Swap
Percent

	Bank A	Company B	Relative Advantage
Credit Rating	AAA	BBB	
Fixed Rate	7.0	8.5	1.5
Floating Rate	LIBOR	LIBOR + .5	.5
Possible Savings 1.5 − .5 = 1.0			

LIBOR: London Interbank Offer Rate.

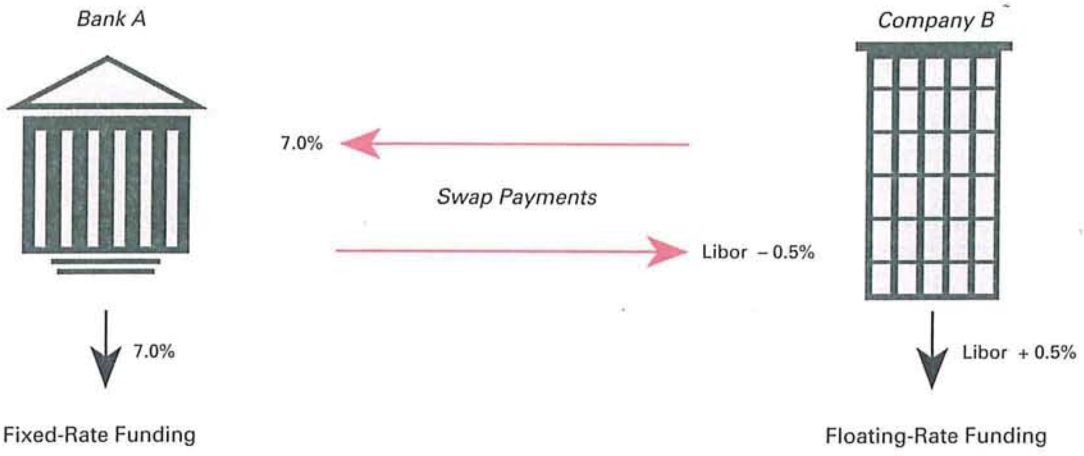
The Pricing of Swaps

Swap dealers quote a floating rate and a fixed rate. The most popular floating rate is either 3-month LIBOR, paid and reset quarterly, or 6-month LIBOR, paid and reset semiannually. LIBOR is usually quoted "flat," that is, without a premium or a discount. The fixed side of the swap is priced relative to the yield on U.S. Treasury securities of equivalent maturity. For example, the fixed rate for a 5-year swap would be the yield on 5-year Treasury notes plus a premium. The premium will differ depending on whether one wants to be a fixed or a floating payer in the swap, reflecting the bid-ask spread required by the dealer. Thus, the 5-year swap might be quoted at 30–33, meaning that the dealer will pay fixed at a 30-basis-point (0.3 percent) premium above the 5-year Treasury yield, or receive fixed at a 33-basis-point premium over that yield.

Unlike interest rates on loans and bonds, swap rates do not vary with the creditworthiness of the

Figure 1

Savings from an Interest Rate Swap



counterparty. Rather, counterparties not deemed sufficiently creditworthy may be required to post collateral or refused the swap altogether.

Table 3 provides an illustration of actual swap rates quoted on September 2, 1992. Perhaps the most striking feature of the swap rates shown are the differences between the fixed and the floating rates and among the rates for various maturities. A fixed-rate payer on a 10-year swap with a notional principal of $10 million (a fairly typical size) would have to pay the floating-rate counterparty $33,800 a year (the difference between the 10-year rate of 6.88 percent and the 3-month LIBOR of 3.5 percent), at least until the floating rates change.

The credit risk of swaps relates only to the cash flows exchanged by the counterparties and does not involve the underlying notional principal. Credit risk arises only when one counterparty defaults—fails to make the agreed-upon interest payments—and interest rates have changed, so that the other party can arrange a new swap only at inferior terms. Default alone does not expose the participants to loss: counterparty B is not obligated to fulfill its side of the transaction if counterparty A defaults. And in the absence of a change in interest rates, presumably counterparty B can negotiate a new swap arrange-

Table 3
Swap Rates on September 2, 1992

Floating Rates	LIBOR (Percent)
3-Month	3.5
6-Month	3.5625
12-Month	3.6875

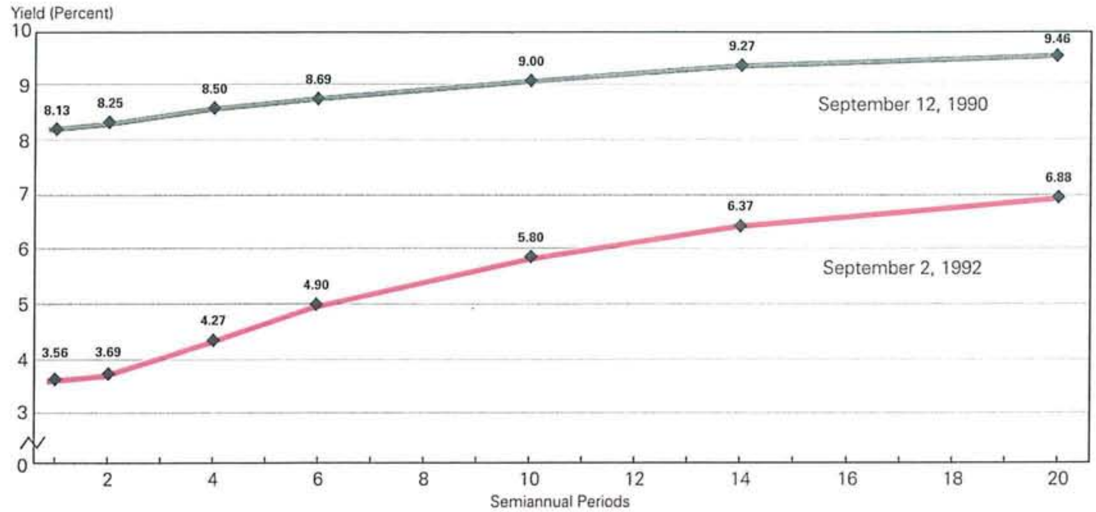
Fixed Rates		Interest Rate Swaps (Basis Points)	Underlying Treasury Yield Curve (Percent)	Actual Rates Paid/Received (Percent)
2-Year	Ask	.21	4.09	4.30
	Bid	.18	4.09	4.27
3-Year	Ask	.35	4.57	4.92
	Bid	.31	4.57	4.88
5-Year	Ask	.33	5.50	5.83
	Bid	.30	5.50	5.80
7-Year	Ask	.37	6.03	6.40
	Bid	.34	6.03	6.37
10-Year	Ask	.38	6.53	6.91
	Bid	.35	6.53	6.88

Rates are as of 1 p.m. New York. LIBOR rates are on an annualized money market basis. Swap rates are on a semi-annual bond equivalent basis.

Source: *American Banker*; Manufacturers Hanover Trust Co.; Fulton Prebon, New York.

Figure 2

LIBOR Swap Yield Curves



Source: *American Banker*; Manufacturers Hanover Trust Co., Fulton Prebon, New York.

ment on the same terms as the old. If interest rates change, however, it may not be possible to replace the swap on comparable terms, and B may experience a loss relative to its experience had A not defaulted.

The whole structure of interest rates on swaps of various maturities, the swap yield curve, is relevant to expectations of future interest rates and thus to the credit exposures on a swap portfolio. The next section will consider the yield curve and its implications for future rates.

II. The Yield Curve

The yield curve is a graph that shows yields to maturity as a function of the instrument's maturity. Figure 2 plots the swap yield curve based on the September 2, 1992 swap yields reported in Table 3. For comparison, Figure 2 also shows the swap yield curve that prevailed almost two years earlier, on September 12, 1990. The chart makes clear that in this two-year period, not only has the level of interest rates fallen dramatically but the yield curve has become much steeper, with the long-term rates exceeding the short-term rates by an unusually large margin.

The yield curve is usually upward-sloping, although at times it has been flat or even inverted, with short-term rates exceeding long-term rates. The unusually steep yield curve prevailing in the past two years has attracted considerable attention and renewed interest in what determines its slope. Two theories attempt to explain the differences in interest rates among instruments of different maturities and the resulting shape of the yield curve.

The first is the expectations theory of interest rate structure, which ascribes the differences in rates across maturities to expectations about future interest rates. In its most basic form, it postulates that the interest rate on a long-term instrument will equal an average of short-term rates expected to prevail over the life of the long-term instrument.

According to the expectations theory, if, for example, 10-year Treasury bonds have a higher yield than 1-year Treasury bills, it is because nominal bill rates are expected to be higher 10 years from now than they are today. Therefore, the yield on a 10-year Treasury bond is an "average" of the successive 1-year rates expected to prevail throughout the 10 years. Similarly, if the yield curve is inverted and the long-term rate is lower than the short-term rate, it is because short-term rates are expected to fall in the future. The expectations theory allows us to derive the rates that are expected to prevail at various times in the future from the current structure of interest rates.

The expectations theory assumes that instruments of different maturities are perfect substitutes, so that investors are indifferent between holding a long-term bond and rolling over a short-term bond over the same period, assuming they can get the same return. In order to unambiguously infer forecasts of future short-term rates from the slope of the yield curve, it is also necessary to assume that investors' expectations are homogeneous.

The second theory, known as the "preferred habitat" theory of interest-rate structure, provides an important qualification of the expectations hypothesis. This second theory maintains that various groups of securities issuers, on the one hand, and investors, on the other, have their own preferred instruments or maturities (habitats), and that supply and demand from these groups govern the premiums that must be paid for funds at different maturities. For example, life insurance companies may prefer to invest in securities with long maturities because these securities match their long-term liabilities. Banks, on the other hand, usually have liabilities with shorter average maturities, and so may be more reluctant to invest in securities with maturities longer than two or three years.

Swaps of higher maturity reach higher lifetime credit exposures, and a rising interest rate pattern results in higher exposure than a random walk without a trend.

The preferred habitat view regards sums of money invested at different maturities as separate commodities and sees changes in their prices (interest rates) as resulting from shifts in supply and demand, just like changes in relative prices for any other goods. Because long-term securities are generally less attractive to the majority of investors than short-term securities, one consequence of this theory is that the term structure will contain a term premium, making the yield curve upward-sloping. Thus, according to this view, the upward slope of the yield curve resulting from the term premium does not necessarily mean that investors expect short-term rates to rise in the future, but may simply mean that more investors prefer shorter maturities to longer ones. Nevertheless, one crucial insight from the expectations theory still holds, namely, if the term premium is constant over time and relative supply and demand for the various instruments do not change, then a change in the slope of the yield curve signals a change in expectations about future rates.

Figure 3 shows the historical accuracy of the yield curve forecast as exemplified by the yield on 5-year Treasury securities.[1] The dashed line shows the yield on 5-year Treasuries, while the solid line shows the average yield on 1-year Treasuries over the following five years. If the yield curve contained an accurate forecast, the solid and the dashed lines would coincide. In reality, the yields on 5-year Treasuries tend to underestimate the future yields on 1-year Treasuries when rates are rising and overestimate them when rates are falling.

Several academic studies have empirically tested the accuracy of the yield curve forecasts for various time horizons. Their evidence suggests that the yield curve has a statistically significant forecasting capability for short-term rate changes over long time horizons, but forecasts poorly for time horizons of more than a few months but less than a year (Mishkin 1990). This suggests that while one need not slavishly follow the yield curve forecast, whether for estimating credit exposures on swaps or for any other purpose, one should at least be aware of it and any differences from one's own forecast. A detailed discussion of interest rate forecasting and the appropriate weight that forecasting models should give to the yield curve are outside the scope of this article. Instead, the article considers two opposite extreme cases: 1) where the interest rate follows a flat path without a trend and 2) where the yield curve completely determines the future trend in interest rates.

Table 4 calculates the expected future interest rates that are implied by the sample swap yield curve

[1] While we are concerned with predictive powers of the swap yield curve, here we are limited to the evidence from the Treasury yield curve. Swaps are a relatively recent phenomenon, and a time series of swap rates of several decades' duration is not available. In practice the difference is not important, however. Fixed rates on swaps are customarily quoted as premiums over Treasuries of comparable maturities. (The floating rate is usually quoted in terms of the 3- or 6-month LIBOR—London Interbank Offer Rate.) Thus, for maturities greater than one year, the swap yield curve is reflected in the Treasury yield curve.

Figure 3

Yield on 5-Year Treasuries versus the Subsequent Average Yield on 1-Year Treasuries over Five Years

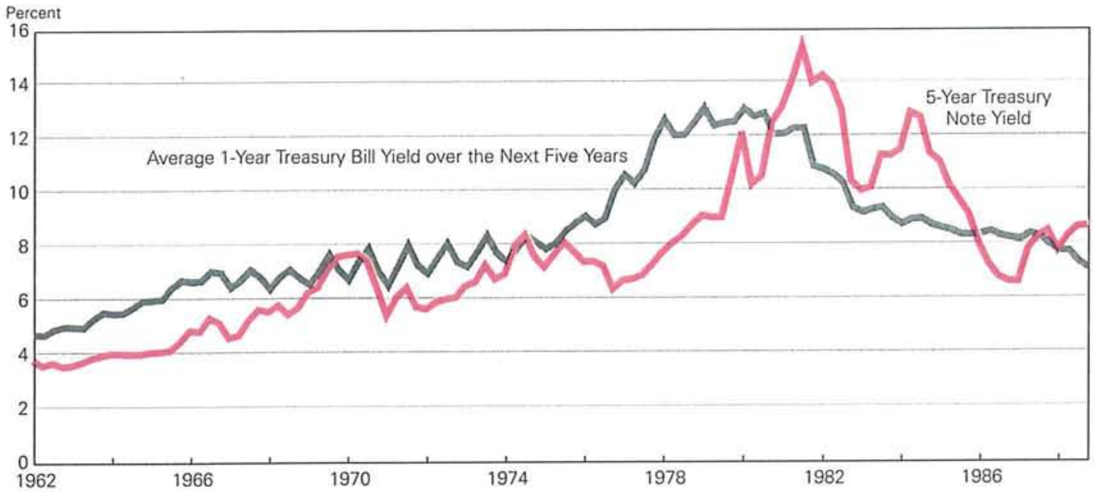


Chart provided by Richard Kopcke.
Source: Board of Governors of the Federal Reserve System.

of September 2, 1992, shown previously in Figure 2. Table 4 shows actual quoted swap rates for the standard maturities, namely 6 months and 1, 3, 5, 7, and 10 years. The 6-month and 1-year rates are LIBOR, while the others are Treasury yields plus a premium. All other swap rates were calculated by interpolating a straight line between the quoted rates. The 6-month forward rates are the rates expected to prevail in each subsequent 6-month period as implied by this yield curve. The calculation of the forward rates from the yield curve is described in the Appendix.

The steeply rising yield curve used in this example implies that short-term rates will rise sharply in the future. It implies, for instance, that the 6-month rate will rise from 3.563 percent in the initial period to 7.847 percent in five years and to 8.508 percent in 10 years.

Table 4
LIBOR Swap Yield Curve and Expected 6-Month Rates

Semiannual Periods	Years	Swap Yields September 2, 1992 (Percent)	6-Month Forward Rate (Percent)
1	.5	3.563	
2	1.0	3.688	3.813
3	1.5	3.979	4.564
4	2.0	4.270	5.149
5	2.5	4.585	5.855
6	3.0	4.900	6.489
7	3.5	5.125	6.485
8	4.0	5.350	6.939
9	4.5	5.575	7.392
10	5.0	5.800	7.847
11	5.5	5.943	7.378
12	6.0	6.085	7.665
13	6.5	6.228	7.953
14	7.0	6.370	8.240
15	7.5	6.455	7.652
16	8.0	6.540	7.823
17	8.5	6.625	7.994
18	9.0	6.710	8.165
19	9.5	6.795	8.337
20	10.0	6.880	8.508

Source: See the text.

III. Monte Carlo Simulations

Relying on forward rates implied by the yield curve is only one approach to forecasting future interest rates. A popular alternative approach is simulating the future path of interest rates as a random walk. The most commonly used models for interest rate behavior over time rely on random walks based on normal and lognormal distributions, with the lognormal distribution having more desirable statistical properties over longer time periods.[2] The lognormal distribution can be described by the following formula:

$$(1) \qquad r_j = r_{j-1} * e^x$$

where x is normally distributed with a mean of zero and a standard deviation based on the historical volatility of interest rates.[3] This distribution gives the generated rate certain important underlying characteristics. First, any changes in the rate are independent of any previous changes in the rate. Second, the rate has no upward or downward trend—it is equally likely to rise and to fall. More specifically, for the lognormal distribution, the rate has an equal chance of doubling or halving over a period of time. Thus, a rate that starts at 10 percent will be equally likely to move to 20 percent or to 5 percent.

These assumptions may be acceptable when the interest rate structure is flat, but when the yield curve slopes up or down, they fly in the face of the expected future rates it implies. It is, however, fairly simple to reconcile the two approaches by incorporating the trend inherent in the yield curve into the random walk generated by a lognormal distribution of interest rates. The easiest way to do this is by adding a constant term to each step of the rate-generating process described by Equation (1), as follows:

$$(2) \qquad r_j = c + r_{j-1} * e^x.$$

The constant term "c" can be chosen such that in the absence of random rate movements, that is, when $x = 0$, the rates would follow the path predicted by the yield curve.

Simulating Swap Exposures

The analysis reported here compared 1) the swap exposures resulting from changes in interest rates based on a simple random walk generated by the lognormal distribution, with 2) the swap exposures resulting from random changes in the interest rate around the upward trend in rates embedded in the yield curve. In both cases, the analysis was done using a matched pair of swaps, where an intermediary (usually a commercial or an investment bank) enters into one swap paying the fixed rate, and into an offsetting swap paying a floating rate. As mentioned previously, the intermediary will earn income through the bid-ask spread, while incurring credit risk of default by one of the counterparties.

Since the swaps are assumed to be matched pairs, only one swap of the pair can have positive market value at any one time. That positive market value is the replacement cost, should the counterparty default. All swaps are assumed to be entered into at par and thus have a replacement cost of zero at the outset. But as the interest rate either increases or decreases relative to the original rate, one swap of the matched pair acquires positive market value. The swap is valued in the same way as a bond with a fixed semiannual coupon. The value is determined by the difference between the original fixed rate and the fixed rate currently prevailing for a swap of comparable remaining maturity. (For simplicity, the counterparties are assumed to exchange interest payments at the same time and the swap is valued in each semiannual period right after the exchange of interest. Thus, the analysis abstracts from the settlement risk or accrued interest.)

For a swap to result in a loss, two events must occur: the swap must be costly to replace, and the counterparty must default.

For example, suppose a bank enters into a matched pair of swaps with counterparties A and B, where the bank pays fixed rate in its swap with A and receives fixed rate in its swap with B. Suppose also that each swap has a notional principal of $10 million,

[2] A popular alternative to the lognormal distribution is a "mean reversion process." It assumes that a certain "natural" level of interest rates would prevail in the economy over the long run, and if the simulated rate deviates significantly from the natural rate, it will be more likely to return to it than to keep drifting at random. The relative merits of the various statistical models for interest rate behavior are discussed more fully in the Bank of England study (Board of Governors of the Federal Reserve System and Bank of England 1987).

[3] The historical volatilities of interest rates used in the simulations reported in this study were calculated by the International Swap Dealers Association (1987). The calculations were based on monthly differences of daily observations between January 1979 and March 1987. The resulting annualized volatilities for swaps of different maturities were as follows:

Swap Maturity	10-yr.	7-yr.	5-yr.	3-yr.	1-yr.
Volatility	.142	.148	.160	.166	.195

a maturity of 10 years, and a fixed interest rate of 7 percent. (In reality, as we have seen before, the bank will receive a slightly higher fixed rate than it pays out but we will ignore that for simplicity.) Suppose that two years after the swaps were put on the books, the prevailing fixed interest rate at which they could be replaced has risen to 8 percent. Assuming semi-annual settlement dates, the market value of the bank's swap with counterparty A is equal to the present value of a stream of cash flows of $50,000: (8%–7%) * $10 million/2 for 16 semiannual periods (the swap now has 8 years left till maturity). If these cash flows are discounted at a semiannual discount rate of 4 percent (half of 8 percent), the present value of the bank's swap with A is $582,615, or 5.8 percent of the notional principal of the swap.

Following the same logic, the market value of the bank's swap with counterparty B is −$582,615 and exactly offsets the market value of the swap with A, so that the bank is insulated from interest-rate or market risk. The bank is not, however, insulated against credit risk. Should counterparty A go bankrupt and default on its swap contract, the bank's loss would equal the replacement cost of the swap, or $582,615. Counterparty B, on the other hand, being in a profitable position on its swap contract, is extremely unlikely to default. Even if B went bankrupt it would continue to perform on this profitable swap. Therefore, the bank's credit exposure to B is zero and the negative market value of the contract does not offset the positive credit exposure to A.

The simulations here were performed for matched pairs of swaps of 10-year, 7-year, 5-year, 3-year, and 1-year maturities. For each matched pair, the starting interest point for the interest-rate simulations was the rate quoted for that maturity on the sample date, namely September 2, 1992. These rates were used as a starting point both for the rising interest rate path predicted by the yield curve and for the purely random interest rate path. Thus, to use a matched pair of 10-year swaps as an example, a random string of 20 semiannual rates is generated, starting with the initial rate of 6.88 percent. This random generation of a string of 20 rates is repeated 5,000 times. For each of the 5,000 generated interest rate paths, the market value of the swap in each semiannual period is calculated.

Market values generated in this way are then discounted to their present values. The discount rate appropriate for each semiannual period being discounted is the interest rate for the corresponding term dictated by the original yield curve. For example, the market value the swap will attain two years from origination is discounted by the 2-year rate, the value it will attain five years from origination is discounted by the 5-year rate, and so on. When the yield curve is upward-sloping, this means that the value in each subsequent semiannual period is discounted at a higher rate and is thus given less weight in calculating the total lifetime credit exposure of the swap. Of course, when the yield curve is flat, this discounting method means that the value of the swap in each semiannual period is discounted by exactly the same rate, that is, the rate at which the swap was originated.

While other discounting methods are certainly possible, this one seems the most intuitively appealing. If the purpose of the simulation exercise is to estimate the appropriate amount of capital to be set aside at origination of the swap against future credit risk, then this capital can be invested at origination and allowed to earn interest until the time it is needed. If, for example, the capital will be needed two years from origination, it can be thought of as being invested at origination for two years at the 2-year rate prevailing at that time, not at some other rate that may prevail in the future.

The discounted market values generated for each semiannual period are then averaged across the 5,000 iterations of the interest rate path, resulting, for example, in 20 credit exposures for a pair of 10-year swaps. In addition, an average *lifetime* exposure is generated for each swap, which is an average of all the semiannual exposures the swap attains in its lifetime.

To the extent that swaps replace on-balance-sheet obligations of counterparties, they reduce rather than increase the credit risk in the financial system.

IV. Results

Figure 4 graphs the discounted expected credit exposures in semiannual intervals for matched pairs of simple fixed-floating interest rate swaps of various maturities. The horizontal axis shows time in semi-

Table 5
Discounted Average Lifetime Exposure on a Matched Pair of Swaps as a Percentage of Notional Principal
Percent

	10-Year		7-Year		5-Year		3-Year		1-Year	
Swap Maturity	Flat Rate	Rising Rate	Flat Rate	Rising Rate	Flat Rate	Rising Rate	Flat Rate	Rising Rate	Flat Rate	Rising Rate
Confidence Limit										
99%	11.22	13.07	7.78	9.49	5.12	6.44	2.25	2.79	.34	.36
95%	8.28	9.24	5.67	6.79	3.59	4.64	1.63	2.02	.24	.25
90%	6.93	7.57	4.71	5.54	3.06	3.75	1.37	1.66	.20	.21
75%	5.12	5.33	3.37	3.75	2.22	2.54	.98	1.13	.14	.14
Mean Expected Lifetime Exposure	4.03	4.27	2.68	2.97	1.74	2.00	.77	.87	.10	.10

annual periods. The vertical axis shows credit exposure as a share of notional principal. The solid lines plot the time path of the credit exposure that results from an interest rate path based on a pure random walk from the lognormal distribution, ignoring the market forecast of future rates. The dashed lines show credit exposure that results from the rising path of interest rates based on the lognormal random walk with the built-in trend that reflects the market forecast of future rates.

The plots reveal several interesting patterns. First, they have a characteristic inverted bowl shape. The exposure is zero at the start since the swaps were put on at par and can be replaced at no cost. Then, as the fixed rate has a chance to diverge from the initial rate, the exposure gradually increases. As the swap approaches maturity, the exposure starts to decline, since fewer and fewer periods remain in which the difference between the initial and the current rates can accumulate. This basic pattern of gradually increasing, then declining exposure holds for all swaps that are entered into at par, regardless of maturity and the level of the initial interest rate.

Second, the longer the swap maturity, the higher the credit exposure will eventually become, because the rates have a longer time to deviate from the initial rates. And third, the upward-sloping yield curve results in higher exposures than a flat yield curve, and the difference in exposure increases with the swap maturity.

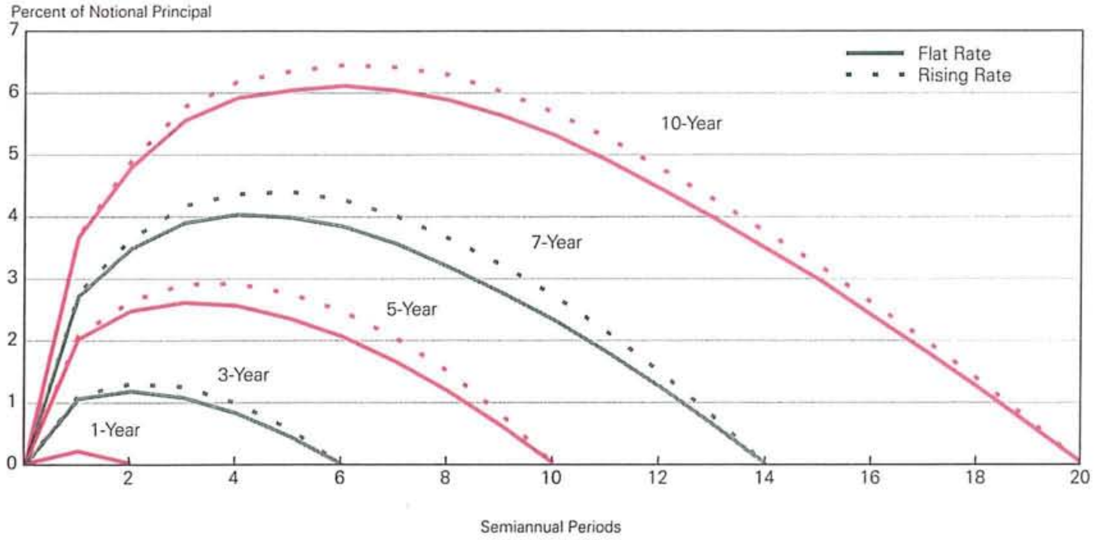
While Figure 4 shows expected credit exposures for swaps *in each semiannual period*, Table 5 reports confidence intervals for average *lifetime* exposure for swaps of each maturity. These estimates are, perhaps, the most relevant measures of the total lifetime credit risk, since they show the confidence intervals for the semiannual exposures averaged throughout the swap's lifetime. These numbers have the following interpretation: 11.22 percent exposure at the 99th confidence interval for the 10-year swap with the "flat" interest rate path means that in only 1 percent of the simulations did the lifetime exposure exceed 11.22 percent of notional principal.[4] Similarly, under the conditions of a "rising" interest-rate path, the exposure exceeded 13.07 percent of the swap notional principal 1 percent of the time. Therefore, given the initial level of interest rates and the interest rate forecast implied by the yield curve, one might assign a potential credit exposure of 13 percent to the 10-year swap. Admittedly, the 99 percent confidence interval implies an extremely cautious measure of lifetime credit exposure, and less cautious estimates may be appropriate. The least cautious measure of lifetime exposure offered by these simulations is the mean expected lifetime exposure, shown in the last row of Table 4. This is simply the average of expected exposures in each semiannual settlement period.

The comparison of average lifetime exposures reveals the same pattern as the semiannual exposures. In particular, swaps of higher maturity reach higher lifetime credit exposures, and a rising interest rate pattern results in higher exposure than a random walk without a trend.

[4] Although the analysis was performed in terms of matched pairs of swaps, the percentages of notional principal shown here should be understood to apply to one swap out of the two in a matched pair, because only one swap out of the pair can present credit risk at any one time.

Figure 4

Discounted Expected Credit Exposures



V. Conclusion

This article has described the use of Monte Carlo simulations to estimate potential credit exposures of simple interest rate swaps. It also has demonstrated a simple way to incorporate an interest rate forecast that is implicit in the yield curve into the simulations. The usefulness of this approach is predicated on the validity of the assumptions imbedded in the model, namely the relevance for the future of the past interest rate volatilities, the appropriateness of the lognormal distribution itself, and the degree to which one wishes to rely on the implicit interest rate forecast from the yield curve.

It must also be emphasized that for a swap to result in a loss, two events must occur: the swap must be costly to replace, and the counterparty must default. These simulations are relevant only for estimating potential exposure, or replacement cost, and have nothing to say about the probability of counterparty default. While it is possible to do a separate credit analysis of the counterparty and treat the replacement cost and the probability of default as two separate problems, they may not, in fact, be independent events for many swap users. In particular, the financial health of many users is directly affected by changes in the absolute level of interest rates, as well as the shape of the yield curve. The asset and liability structure of many banks and thrifts, for instance, is such that they are more profitable at times when interest rates are low and the yield curve is steep. They are, thus, unlikely to default under such circumstances even if their swaps have high replacement costs for their counterparties. At the same time, since weaker counterparties tend to pay fixed and receive floating in swap transactions, they are unlikely to default on their swap contracts when interest rates move higher.

These factors may partially account for the favorable default history swaps have enjoyed so far.[5] The swap market also has developed various modifications to the "plain vanilla" swap contract over the past few years, at least some of which minimize the credit risk of swaps. One such modification consists of marking the swap to market at periodic intervals and requiring the counterparty whose side has a negative market value to make a cash payment to the counterparty whose side has a positive value, after which the interest rate is reset at the current rate. Another variation consists of limiting the maximum

[5] A recent survey by the ISDA and Arthur Andersen & Co. estimated that actual default losses on swaps amount to 0.02 percent of the outstanding notional principal. See ISDA (1992).

size of potential swap payments by combining swaps with interest rate caps, floors, and collars. By buying a cap, for example, a floating-rate payer will never have to pay more than a certain percentage above the initial floating rate. While this would reduce credit risk, it would also expose the seller of the cap to interest rate risk or, alternatively, make it necessary for the seller to buy a hedge for the cap, thus increasing costs. Such variations of swap contracts, while valuable in reducing credit risk, incur higher administrative costs, and they still account for a small proportion of the market vis-à-vis plain vanilla swaps.

Bank regulators have recognized the credit risk of swaps and instituted capital requirements for them and for other off-balance-sheet activities, as part of the new risk-based capital requirements for banks. These requirements were developed as part of the international Basle Accord, which standardizes capital requirements among the commercial banks of the 12 industrialized nations. The new requirements call for banks to hold capital equal, at a minimum, to 8 percent of "risk-adjusted assets." Swaps are included in the calculation of the risk-adjusted assets by being converted to "credit-risk equivalents," or estimates of credit risk that make them comparable to loans and other on-balance-sheet items. For interest rate swaps, the credit-risk equivalent is equal to one-half of the sum of 1) the replacement cost of the swap and 2) 0.5 percent of the notional principal if the swap's maturity is greater than one year. Capital must be held against the credit-risk equivalent, just as it would be against loans and other assets.

A number of large swap dealers have addressed their counterparties' concern over credit risk by setting up separately capitalized "special purpose vehicles" (SPVs) that are capitalized highly enough to merit the highest rating from credit-rating agencies. Despite such efforts, however, the phenomenal growth of the swap market in the past decade assures that swap credit exposure will remain a concern both for intermediaries and final users. It is important to keep in mind, however, that swaps confine credit exposure to net differences in cash flows and do not involve the underlying notional principal. To the extent that swaps replace on-balance-sheet obligations of counterparties, they reduce rather than increase the credit risk in the financial system.

Appendix

As a general rule, the relationship between a long-term rate prevailing at any time and the sequence of expected short-term rates expected to prevail in the future can be expressed by the following formula:

$$(1 + r_0^N) = \prod_{i=1}^{N} (1 + r_i^0)^{1/N} \qquad \text{(A1)}$$

where r_0^N is the long-term rate of return on a security of term N and r_i^0 is the short-term rate of return prevailing in each subsequent period i.

Specifically, if according to the swap yield curve in Figure 2, the current 1-year rate is 3.688 percent, and the current 6-month rate is 3.563 percent, then the 6-month rate six months from now is:

$$((1 + 0.03688)^2/(1 + 0.03563) - 1) \times 100 = 3.8127 \text{ percent.}$$

Similarly, if the current 1.5-year rate is 3.979 percent, and the first two successive 6-month rates are as above, then the expected 6-month rate a year from now is:

$$((1 + 0.03979)^3/(1 + 0.035625)(1 + 0.038127) - 1) \times 100 = 4.5637 \text{ percent.}$$

This process can be iterated until each successive expected 6-month rate is derived from the relevant long-term rate and all the previously derived expected 6-month rates. The results of these calculations are shown in Table 4.

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