Assessing Market Risks and Credit Risks of
Long Term Interest Rate and Foreign Currency Products

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1. Introduction

    The central banks of the major industrialized countries are currently
engaged in a discussion of how to set capital requirements for commercial
banks. The purpose of this paper is to develop a model of interest rates and
foreign currency to provide a uniform method of evaluation capital
requirements of long term assets and liabilities in interest rates and foreign
currencies.

    To put the discussion on a concrete footing, suppose a US commercial
bank has agreed to a five year swap, paying Sterling ( ) at 10.5% and
receiving Deutschemarks (DM) at 9% with a counterparty, with the exchange of
principals of 5.21MM against DM 15MM at the end of the 5 years. The question
faced by bank management and regulators is: how much capital does the bank
need to support potential losses in this transaction?

    In this paper, we consider two types of risks: market risk and credit
risk. Market risk refers to the potential losses from adverse movements in
exchange rates and interest rates. Credit risk refers to the potential losses
from a default by a counterparty. Take the case of the five year swap.
Suppose the bank closes out this position two years prior to maturity.
Exchange rates and interest rates may have moved in such a way to make the
Dollar value of Sterling receivables less than the Dollar value of
Deutschemark payables in the remaining two years. The bank can only close out
this position by paying this difference to the counterparty, and must
therefore suffer a loss. This is what we mean by market risk.[1]

    The bank could avoid market risks by holding a matching position with
another counterparty. The hypothetical 5 year currency swap (paying   and
receiving DM) would be matched by an opposite currency swap (paying DM and
receiving) with a second counterparty. The market values of these swaps
move in exactly opposite directions. On net, their combined market value is

zero, so the matched swaps have no market risk. But the bank is still exposed
to credit risk. Suppose the second counterparty defaults. The bank is now
back in the original position. In most cases, the default occurs when the
defaulting party has a negative market value position vis-a-vis the bank, so
that the bank must take a loss if it is unable to obtain payments through
litigation. In this case, the amount of the loss equals the market value of
the position at the time of the default. This is what we mean by credit risk.

This discussion points out that the first step to measure market risk
and credit risk is to determine the distribution of the market value of an
asset at each point in time over its remaining life. The method for
calculating market values is discussed in Section 2. It is shown to depend on
future interest rates and exchange rates. The distribution of future market
values are obtained by simulation using a statistical model of interest rates
and exchange rates, which is developed from historical data, as done in
Section 3. The second, and more controversial, step, is to quantify potential
future losses, based on the simulation results. In Section 4, we provide
several ways to quantify risk exposure.

2. Calculating Market Values

In this section, we use the discounted cash flow method to calculate the
market value of a swap. A swap position can be represented by a stream of
cash flows, denoted by $\{CF_{i,\tau},\ \tau=1,..,T,\ i=1,...,I\}$. The index i is over
currencies, and the index τ is over time to maturity, measured in months. For
example, the 5 year swap discussed in Section 1 can be given as follows:

τ		DM
(month)	(MM)	(MM)
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	-0.547	+1.35
7	0	0
8	0	0

9	0	0
10	0	0
11	0	0
12	-0.547	+1.35
.		
.		
18	-0.547	+1.35
.		
.		
.		
60	-5.757	+16.35

where a minus sign denotes cash outflow and a plus sign inflow for the bank.

The market value of this cash flow can be calculated using a discounting formula. Let $\{r_{i,\tau}, \tau=1,..,T\}$ be the discount rates for currency i with time to maturity τ, and S_i the spot exchange rates between currency i and the home currency (US\$ in this case). The market value of this cash flow is:

$$V = \sum_i S_i \left[\sum_\tau CF_{i,\tau}/(1+r_{i,\tau})^\tau \right].$$

The distribution of V at any point in the next five years can be obtained by simulating the path of S_i and $r_{i,\tau}$.

Before proceeding to discussing how to build a statistical model to simulate the path of future exchange rates and interest rates, several remarks are in order.

One, we have assumed that the cash flows are known and fixed in advance. This is true for the currency swap in our example. In general, however, cash flows can be stochastic, as in the case of a floating-fixed interest rate swap or currency option. In a later section, we will discuss how to deal with stochastic cash flows.

Two, the analysis is not restrict to analyzing the market value of a single transaction. It can be carried out for a portfolio of transactions. A commercial bank tends to deal with one counterparty repeatedly. We can simulate the market value of all transactions with that counterparty to obtain an overall exposure with respect to that particular counterparty. Bank regulators may also want to simulate the market value of all trades undertaken by a single bank to ascertain the exposure of the entire bank.

Three, we are using a monthly model for exchange rates and interest

rates. This is done for several reasons. Ideally we would like to find the distribution of market values *at any time* during the life of the asset, which would require simulating on a daily basis. But the smaller the time step of our simulation, the more computing time it requires. To balance these factors, a monthly model is selected. Furthermore, there are severe constraints on the availability of historical data. Other than the monthly data in the International Financial Statistics tapes, we know of no other source which allows us to construct comparable data for exchange rates and interest rates across many countries.

Four, we model only a 3-month and a 10-year interest rate for each country to reduce the amount of simulation. We assume a linear term structure of interest rates and interpolate linearly between them for interest rates of other maturities. In principle, we can model the entire term structure of interest rate in each country, but this would require much more data than are available, and the simulations would take much longer to do.

We now proceed to discuss the statistical model which is used to simulate future interest rates and exchange rates.

3. Statistical Model of Interest Rates and Exchange Rates

Let us first review what is needed in our statistical model. For each country, we need a 3-month interest rate, a long term interest rate (which is assumed to be a 10 year rate), and the exchange rate against the US Dollar. The starting point of our analysis is June 1973. This corresponds roughly to the start of the floating exchange rate regime. The end point is December 1990, the last full year of data. This gives 210 observations per series. To illustrate our methodology, we obtained data for the United Kingdom (BP), Germany (DM), Japan (JY), and the United States (US).

The International Financial Statistics (IFS) tapes are the primary source of our data. The exchange rate is the end of month market rate (Line ag). The long term interest rate is the "government bond yield" (Line 61). Since the bond yields are averaged over the month, we filtered the rates of

change through a first order moving average to remove any induced correlation. [See Working (1960).] Our short term interest rate is the 3-month Eurocurrency interest rate. For the US, the end-of-month 3-month Eurodollar data are obtained from the Statistics Department of Board of Governors of the Federal Reserve System. For the other three countries, the 3-month Eurocurrency interest rates are constructed via the covered interest arbitrage condition, using the end-of-month 3-month forward premia in Line 60f of the IFS tapes and the 3-month Eurodollar interest rate.

Table 1 provides a description of the rates of change of the data, defined as the logarithmic difference of successive months, multiplied by 100. None of the means are statistically different from zero. The standard deviations of the bond yields and exchange rates are similar, and both are smaller than those of the Eurocurrency rates. In particular, the Eurodollar has the largest standard deviation. There is also little evidence of serial correlation, except for the first lag in the case of the 3-month Euro-Yen interest rate. There is, however, ample evidence of nonnormality. Seven of the eleven series have coefficients of excess kurtosis which are statistically greater than zero. [Two of these seven also have evidence of skewness as well.]

Based on this evidence, we decide to conduct our simulation as follows. For the purposes of this paper, we start the simulation at the values of interest rates and exchange rates at the end of 1990. The bank's initial value of the hypothetical 5 year currency swap is -$0.56MM. In other words, the market value of the receivables is below that of the payables from the bank's point of view. Let $x(0) = [x_i(0)]$ be the vector of these 11 starting values of interest rates and exchange rates. The value at the end of the next month, $x(1)$, is given component by component as follows:

$$x_i(1) = x_i(0) \exp(z_i),$$

where the vector of $z = [z_i]$ is draw randomly, with replacement, from the 210 vectors of rates of change. This procedure is repeated recursively, so that a time path of the 11 variables over the next five years are generated. We then

replicate this 10,000 times.

A few comments regarding this method are in order. First, we draw randomly (with replacement) from the observed data. This provides the unconditional distribution of the data, which ignores any conditional dependence, such as autocorrelation or conditional heteroskedasticity, in the data. We deem this to be appropriate for long term instruments, since we believe that rates of change of exchange rates and interest rates are stationary and ergodic.   Second, we draw the entire vector of z. This preserves the contemporaneous covariance structure between the 11 variables.

4. Simulating the Distribution of Market Values

The simulation generates a lot of numbers. In each of the 60 months of the currency swap, there are 10,000 simulated values of the market value. These must be summarized in a useful way. We have selected three sets of numbers which convey the most information about the exposure of the bank.

First, we present the market risk of the hypothetical swap position in the form of the distribution of the "maximum drawdown." Here, we assume that the position is actually marked-to-market at the end of each month, exactly analogous to a futures position. Specifically, we compare the market value of the position at the beginning and the end of the month. If the value of the bank's position increased (which means that of the counterparty has decreased by the identical amount), the counterparty pay the bank the difference. If the value of the bank's position decreased (which means that of the counterparty has increased by the identical amount), the bank pays the counterparty the difference. The maximum drawdown, from the point of view of the bank, is the maximum cumulative loss during the life of the position.

Even though the positions are not actually marked-to-market, the maximum drawdown is a useful concept in determining market risk. Suppose the bank decides to liquidate the position, for any number of reasons. The bank will receive the market value of the position at liquidation. The maximum drawdown is the upper bound of the loss incurred by the bank at the liquidation of the

swap position.

For the 10,000 replications, we report the quantiles of the maximum drawdowns in Table 2, using the 1%, 5%, 10%, 25%, 50%, 75%, 90%, 95%, and 99%. According to the simulations, there is a 1% chance that the maximum drawdown will exceed $5.85MM, i.e., 99% of the time, the maximum drawdown is less than $5.85MM. There is a 5% chance that the maximum drawdown will exceed $4.28MM. There is a 10% chance that the maximum drawdown will exceed $3.52MM. There is a 25% chance that the maximum drawdown will exceed $2.50MM. There is a 50% chance that the maximum drawdown will not exceed $1.54MM. The amount of bank capital set aside for absorbing losses from the hypothetical 5 year currency swap must be related to this distribution. The more conservative the approach, the higher the capital required. Without further specifying a theory of risk taking for the firm, we are unable to determine which is the "optimal" level of risk and the associated capital needs.

Second, we present the credit risk of the hypothetical swap position in the form of the distribution of the "maximum replacement cost". Suppose the counterparty declares bankruptcy prior to the maturity of the hypothetical 5 year currency swap. The cost to the bank is to replace this counterparty with another. If the counterparty's position has a negative market value, then no other party would be willing to assume this position, unless the market value is reset to zero. In other words, the cost of replacing the counterparty to the bank is the loss of the bank's positive market value.

In the simulations, we calculate the maximum value of the bank's position during the 5 years. We call this the "maximum replacement cost". Its distribution is also given in Table 2. This is how we interpret the results. There is a 1% chance that the bank will have to pay more than $10.61MM to induce a second party to replace the original counterparty, should the counterparty defaults, i.e., 99% of the time, the replacement cost will be less than $10.61MM. There is a 5% chance that the replacement cost will exceed $8.2MM. There is a 10% chance that it will exceed $7.03MM. There is a 25% that it will exceed $5.19MM. And there is a 50% chance that it will

exceed $3.48MM.

It is useful to discuss the relevance of these simulations. Suppose the bank wishes to provide a loss reserve for the market risks of these swap positions. In our example, a reserve of $5.85 MM would cover the maximum market loss 99% of the time, while a reserve of $1.54 MM would cover the maximum market loss 50% of the time, given that the loss must be realized, i.e., that the swap position must be closed out. When the loss is not realized, of course, the reserve would not actually be used. The actual amount of reserves, therefore, would be less than this amount, since the probability that the loss must be realized at the point of maximum drawdown is less than one. It is, however, outside the framework of our analysis to determine the latter probability.

The bank may also wish to provide a reserve against credit risks of the swap position. In this case, a reserve of $10.61 MM would cover the maximum credit loss 99% of the time, while $3.48 MM would cover the maximum credit loss 50% of the time, given that the counterparty defaults. Again, the actual amount of reserve, however, would be smaller than these amounts, since the probability that the counterparty defaulting is less than one.

While there appears to be a conflict in these two sets of numbers, this is really not so. The "maximum drawdown" criterion is designed to measure market risk or financial risk. But the "maximum replacement cost" criterion is designed to measure credit risk, although it is incomplete, the reason being that we do not have default probabilities of the counterparty. The numbers in Table 2 under "replacement cost" are conditional on a default. They should be multiplied by the default probability to make them unconditional "replacement cost," which would make them much smaller.

5. The Treatment of Other Instruments

In this section, we briefly discuss how we can modify this model to analyze other types of instruments which are traded in the interest rate and foreign exchange market.

5.1. Foreign Currency Forward Contract

In a forward contract, there are only two fixed cash flows, which occur at the maturity of the forward contract. Our method is trivially extended to cover these contracts. In fact, we can think of the 5 year fixed rate swap as a series of forward transactions.

5.2. Floating-Fixed Interest Rate Swaps

Suppose the hypothetical position is a 5 year swap, paying   on floating 6 month LIBOR, and receiving DM at 9%. Since the DM cash flows are known, we can value them as before. But the   cash flows are random. However, we know that the value of the   position is exactly par after each interest rate reset. In between these resets, the value of the   side equals the discounted value of a fixed sum of interest and principal, payable at the next time the rate is reset.

Oftentimes, the floating rate side includes a spread above (or below) the LIBOR rate. For example, the 5 year swap may require paying   on floating 6 month LIBOR plus 1%, and receiving DM at 9%. In this case, we can treat this as a portfolio consisting of two interest rate swaps: (a) paying   on floating 6 month LIBOR and receiving DM at 9%, and (b) paying   at a fixed rate of 1% and receiving   at a fixed rate of 0%.

5.3. Floating-Floating Interest Rate Swaps

Suppose the hypothetical position is a 5 year swap, paying   on floating 6 month LIBOR, and receiving DM also on floating 6 month LIBOR. We can value the two sides of the transaction as follows. Each time when the interest rates are reset, the values of the   and DM positions are exactly par. In between resets, the value of the each side equals the discounted value of a

fixed sum of interest and principal, payable at the next reset date.

When the floating rates include a spread above (or below) LIBOR, we can treat them as combinations of three swaps. For example, suppose the hypothetical position is a 5 year swap, paying on floating 6 month LIBOR plus 1%, and receiving DM also on floating 6 month LIBOR plus 1.5%. This is the same as the portfolio of three swaps: (a) paying on floating 6 month LIBOR, and receiving DM also on floating 6 month LIBOR; (b) paying on a fixed rate of 1% and receiving at a fixed rate of 0%; (c) receiving DM on a fixed rate of 1.5% and paying DM on a fixed rate of 0%.

5.3. Foreign Currency Options

Suppose the hypothetical position is the right to buy DM and pay in 5 years. We need to simulate the value of the option price over the 5 years. This requires an option pricing model. We use the Garman and Kohlhagen (1983) model, although any other model will suffice. In each month during the 5 years, we use the simulated data to in the option pricing model, including the "historical volatility" parameter.

If we have an American-style option, then we to calculate the early exercise value. We can use the Baroni-Adesi and Whaley (1987) approximate solution to the American option in place of the Garman-Kohlhagen model.

5.4. Interest Rate Options

Interest rate options, such as caps and floors, can be treated in a manner similar to currency options. These options typically require the term structure of forward interest rates. As we have discussed earlier, we have built a term structure into our model, so we can use this to evaluate interest rate options.

5.5. Portfolios

We have mentioned before, and we emphasize here, that we can treat a

portfolio of the above instruments as a totality. This can be done to evaluate the market risk and credit risk in relation to all transactions against the same counterparty, or for the bank as a whole.

6. Conclusion

In this paper, we have provided the minimal statistical model which can be used to analyze the market risk and credit risk of long term interest rate and exchange rate instruments. We show how to do this in the context of a fixed-fixed interest rate swap in detail. We also mention briefly how to deal with other types of position, e.g., fixed-floating and floating-floating interest rate swaps, currency forward contracts, currency options, and interest rate options. Furthermore, a portfolio can be formed to assess the market risk and credit risk in relation to all transactions vis-a-vis a single counterparty, or the transactions of the entire bank.

Notes:

1.   Currently, swap positions are off balance sheet items, and are not
     marked to market. If the swap position must be marked-to-market, then
     the bank would face market risk at each valuation date, regardless of
     whether the position is actually closed out or not.

References:

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