Integrating Interest Rate and Currency Risk Management

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Building on recent arbitrage-based pricing innovations in finance, we demonstrate an integrated interest rate and currency risk evaluation and management approach. This approach is based on the six fundamental parameters of global money market risk, exchange rate standard deviation, interest rate standard deviations and the correlations across interest rates and currencies. Based on these parameters, an internally consistent scenario set is generated. These scenarios both define the state-space of our pricing and hedging method, and are readily interpretable in a managerial context. This approach provides an integration of financial derivatives-based strategies and business scenario analyses.

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Abstract

Building on recent arbitrage-based pricing innovations in finance, we demonstrate an integrated interest rate and currency risk evaluation and management approach. This approach is based on the six fundamental parameters of global money market risk, exchange rate standard deviation, interest rate standard deviations and the correlations across interest rates and currencies. Based on these parameters, an internally consistent scenario set is generated. These scenarios both define the state-space of our pricing and hedging method, and are readily interpretable in a managerial context. This approach provides an integration of financial derivatives-based strategies and business scenario analyses.

Historically, global currency and interest rate risk have been managed separately. That is, global activities such as funding, lending, trading currency and swap positions, hedging, transfer pricing, and deciding the mix of corporate assets and liabilities have typically been segregated into domestic and foreign segments. In the rare cases when these activities have been integrated, the resultant risk analyses have largely been used to support continued delegation of rate and currency management by geographic regions.

However, developments in evaluating and managing domestic interest rate risk have, recently, been extended across currencies. These extensions permit both delegated and integrated interest rate and currency, as well as business risk, analyses. Most importantly, the associated analytical framework is consistent with the fundamental logic and insights of derivatives pricing theory.[1]

In this paper, we develop an example which documents how separate management of domestic and foreign risk does not adequately control value deviations that occur across rate and currency scenarios. Generally, corporate-wide risk management transactions must undo components of the purely domestic- and foreign-based initiatives. Nevertheless, local initiatives are not precluded in the cases in which local advantage exists in managing risk-related transactions. In these cases where local advantage exists, a natural corporate-wide risk management overlay may also be used.

Our example addresses three sources of risk: a domestic (U.S.) term structure of interest rates, a foreign (U.K.) term structure of interest rates and a currency (pound) exchange rate. These three risks are characterized by six parameters which govern the range of movement (two rate and one currency standard deviations) and the expected relationships between rate and currency movements (a rate correlation and two rate-currency correlations).

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[1] Following Amin-Jarrow (1991) and Amin-Bodurtha (1994), the the Ho-Lee (1986) and Heath-Jarrow-Morton (1992) arbitrage-based domestic rate models are extended to the two (or more) country case. See Cox-Ingersoll-Ross (1985) and Nielson-Saá-Requejo (1993) for an alternative equilibrium-based approach. Harrison-Kreps (1979) and Harrison-Pliska (1981) provide the fundamental theory.

To justify our approach, we consider the example of a U.S. parent corporation with two equal-size plants, one in the U.S. and the other abroad. In this example, each plant's production is sold in its local market. The current planning cycle is one year, and the plant-product lives are set at two years.

Under the one year planning horizon, the maintained risk management criterion is one of minimizing ***value*** variations (deviations) as of year end. All payments and receipts (income, interest and principal) are carried forward or backward (as appropriate) to year end by present- and/or future-valuing all cashflows along their respective term structures. The value-deviation minimization criterion is chosen to unify income statement and balance sheet management under one objective. However, the advocated risk management approach can be used for separate income- or equity-related management.

Exhibit 1 depicts the corporation of interest. The corporation has $100 million of plant and equipment, split equally between the two countries.

Exhibit 1
The Corporation

	current	short-term	long-term
parent			
$ assets			
plant	50.0		
foreign sub.	20.0		
$ liabilities		5.0	25.0
$ equity	40.0		
subsidiary			
fx assets			
plant	50.0		
fx liabilities		5.0	25.0
fx equity	20.0		

From Exhibit 1, we see that each plant is, or will be, funded by $20 million in equity and $30 million of debt. For each plant, the largest share of debt, $25 million, is planned for issue at fixed rates. The remaining debt, $5 million, will float with six month LIBOR. The corporation faces risks from several sources: potential costs of their floating rate debt, opportunity loss from the fixed yield on the predominant share of their liabilities, domestic interest rate effects on the domestic operation's income, and the combined rate and foreign currency risks embodied in foreign income and debt-related payments.

For this corporation, equity and debt values must be consistent with initial interest rate and currency levels. Furthermore, these values must be consistent with specified rate and currency price evolution. As we highlight, this requirement is met by the income generated across scenarios. In our example, the value derived from domestic output is related to domestic rate levels, and the value derived from foreign output is related to domestic rate, foreign rate and currency price levels.

We develop our example in two steps. First, we outline the domestic operation's characteristics, risks and values. Since the risks in this operation are driven only by domestic interest rate risk, they provide a useful starting point for discussion of more complex foreign operation risks. Secondly, we define foreign rate and currency movements and correlate them with domestic rate movements. We use these correlated rate and currency movements to generate a benchmark set of business scenarios. Subsequent scenario analysis provides the rationale for preferred risk management choices.

The Domestic Interest Rate Situation

To evaluate the values and risks of domestic currency income- and liability-related payments, we first define the current domestic term structure and its potential evolution. Exhibit 2 provides the necessary information.

The initial exhibit panel lists the rates that prevail at the beginning of our example (time 0.0). The rates discount certain cashflows back to present values. The 5.253 annual (0.0 to 1.0) discount rate implies that a claim to one hundred dollars at year end is worth $94.88 today. The 5.319 semi-annual "0.0 to 1.0" year bond yield is set so that a one year maturity bond paying this yield has par value (discount 5.319/2 twice plus the discounted value of $100 in principal equals $100). The one and a half and two year maturity bond yields are determined analogously.

The forward rates are stated on a continuously compounded and 365-day annualized basis. These rates are set so that an initial $100 investment or loan, when rolled over at six month intervals, maintains a present value of $100. These forward rates, when translated to a "simple interest" basis, are the rates at which six month forward rate agreements (FRA) would be set. If we assume zero bid-ask spreads, these forward rates ensure that interest rate swaps (with fixed rates set to the bond yields) will be exactly hedged by the associated maturity strip of FRAs. At time 0.0, interest rate swaps set at these fixed yields and floating rates have zero value.

The second panel of Exhibit 2 (time 0.5) outlines our domestic interest rate evolution assumptions. Domestic forward rates evolve simply. That is, rates increase or decrease with equal probability, and by an amount proportional to the rate standard deviation. The example rate standard deviation is set at the historical annualized estimate for the 1981 to 1993 period (2.6%). Consistent with fair (arbitrage-free) pricing, a small deterministic movement or drift also affects the rates.[2]

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[2] This drift occurs because the expected values of interest rate-related cashflows must be compounded. Expectations, or multiplying outcomes by associated probabilities, result in small mathematical adjustments. These adjustments are necessary to account for the different effects of adding probabilities, while interest rate effects multiply through the compounding process. Importantly, the drifts differ according to the length of the compounding period until the forward rate is initiated (i.e., the 0.5 to 1.0 year forward rate drift is smaller than the 1.0 to 1.5 year drift).

Exhibit 2

Initial Domestic Term Structure[3]

time 0.0	years	0.0 to 0.5	0.0 to 1.0	0.0 to 1.5	0.0 to 2.0
discount rate		5.006	5.253	5.500	5.746
bond yield			5.319	5.567	5.811
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0
forward rate		5.006	5.500	5.993	6.484

Domestic Term Structure Evolution
(2.6% rate standard deviation)

time 0.5	years	0.0 to 0.5	0.5 to 1.0	0.5 to 1.5	0.5 to 2.0
discount rate		up	7.347	7.602	7.856
bond yield		up		7.999	8.250
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0
forward rate		up	7.347	7.856	8.365
	years	0.0 to 0.5	0.5 to 1.0	0.5 to 1.5	0.5 to 2.0
discount rate		down	3.670	3.925	4.179
bond yield		down		4.216	4.468
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0
forward rate		down	3.670	4.180	4.688

time 1.0	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.0 to 2.0
discount rate		up	up	9.703	9.966
bond yield		up	up		10.212
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0
forward rate		up	up	9.703	10.229
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.0 to 2.0
discount rate		up (down)	down (up)	6.026	6.289
bond yield		up (down)	down (up)		6.385
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0
forward rate		up (down)	down (up)	6.026	6.552
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.0 to 2.0
discount rate		down	down	2.349	2.612
bond yield		down	down		2.627
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0
forward rate		down	down	2.349	2.875

[3] Both the discount and forward rates are annual and continuously compounded, while the bond yields are stated on an actual-365 day semiannual basis.

Using the 1.0 to 1.5 year forward rate as an example, we observe the following rate movements:

next forward rate		=	initial forward rate	+	drift	+ or -	standard deviation
up -	7.856	=	5.993	+	0.025	+	$2.60*\sqrt{0.5}$
				or			
down -	4.180	=	5.993	+	0.025	-	$2.60*\sqrt{0.5}$

To ensure that the rate change scale and time interval are consistent, we scale the standard deviation by the square root of the time interval. Annual rates are likely to range within one standard deviation, plus or minus, from the current rate level. Half-year rates are likely to be in a range that is approximately 70% of the annual range. Since the square root of one-half adjustment equals 0.707, our adjustment appropriately scales the half-year rate range.[4]

Exhibit 2 also lists discount rate and bond yield movements. In both up and down rate scenarios, the discount rate and bond yield moves are calculated from the associated forward rate curves.

Over the second six month period, rates will, again, increase or decrease. Four rate scenarios are possible:

next forward rate		=	last rate	+	drift	+ or -	standard deviation
up-up	9.703	=	7.856	+	0.008	+	$2.60*\sqrt{0.5}$
				or			
up-down	6.026	=	7.856	+	0.008	-	$2.60*\sqrt{0.5}$
				or			
down-up	6.026	=	4.180	+	0.008	+	$2.60*\sqrt{0.5}$
				or			
down-down	2.349	=	4.180	+	0.008	-	$2.60*\sqrt{0.5}$

In this second period, Rates move as they did over the first half year, but with slightly smaller drift. Note also that two of the scenarios generate the same rate outcome, up-down and down-up. In both cases, rates return roughly to their initial level. Hence, these two scenarios may be combined into a "stable" rate scenario.[5]

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4 For shorter intervals, the associated adjustments are daily (5%), weekly (14%), monthly (29%), quarterly (50%). As time lengthens, this scaling widens the likely range less and less. For a four year interval, the upper and lower likely range limits are only two standard deviations, 5.2%, to each side of the current rate (plus drift) for our example.

5 Of additional interest is the difference between these stable rates and the initial 1.0 to 1.5 year forward rate, 5.993%. This difference is equal to the sum of the rate drifts which occur over the two half-year intervals (0.34%). Therefore, the stable rate scenario is one in which rates are expected to rise from their initial forward rate level. Furthermore, the four rate scenarios have equal probability of occuring, and the expected 1.0 to 1.5 year rate level is 6.026%. We see that the initial forward rate is not the expected future interest rate, but is biased downward. The 1.0 to 1.5 year futures interest rate is equal to

Half-year rate change effects on the corporation can be evaluated in a similar manner. In both the up and down rate scenarios, discounted values of future income and liability financing will change. When rates increase, future income is higher but is also discounted at higher rates, while the fixed rate liability values fall. When rates decrease, the opposite is true. Therefore, our corporation is open to domestic interest rate risk. We now identify these risks and discuss their management.

The Domestic Operation's Interest Rate Risk

If future interest rates and currency values equal the current associated maturity futures contract rates and prices, then output values will be unaffected. In this case, the domestic plant's semiannual output will net $13.4 million. Otherwise, the value of domestic output will be positively related to the domestic interest rate level.

Specifically, output will be proportionally higher if future rates rise above their current futures contract implied values. This link is made to correspond to a business cycle-induced relationship between output and interest rates. The specific rate-induced output adjustment is based on 25% of the difference between initial rate levels and the realized rate level. The $13.4 million stable rate environment output level is scaled proportionately to account for this factor (upward with higher rates and downward with lower rates).

All domestic operation cashflows are converted to their year-end values. The first half year semi-annual dollar income and interest payments are brought forward to year-end, while the second year income streams, interest payments and principal repayment must be brought back. Therefore, the year-end values of these flows depend on interest rate evolution.

Exhibit 3 depicts the corporation's domestic year-end value components. These values are separated into rate scenario, time of payment and payment category. In this exhibit, we emphasize four effects of higher rates:

If rates initially rise, first period income and interest cashflows will have higher year-end values (due both to the positive business cycle effect and to the higher rates earned on invested funds).

Higher first period rates cause higher first and second period (year-end) floating rate-linked payments. [The first period (time 0.5) interest payment is also carried forward to year-end at a higher rate.]

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the expected spot interest rate. The reason for this expected rate-futures rate relationship is that a futures contract is marked-to-market in each period. Hence, futures contract profits and losses are compounded at prevailing interest rate levels, and the futures rate is equal to the forward rate plus the compounding-induced drift. Forward rate contract profits are not marked-to-market, and hence are not compounded over their lives at prevailing rates. For a representative risk-indifferent investor, the futures contract is a fair bet in terms of compounded interest rates, while forward rate contract is not.

Exhibit 3
Domestic Operation Year End Dollar Cashflows
($5 million floating rate and $25 million fixed rate debt)

Year-end scenario	flow	0.5	1.0	1.5	2.0	Year-end total
rates up-up	+ income	13.9	13.5	12.9	12.2	52.5
	+ float	-0.131	-5.187			-5.319
	+ bond	-0.754	-0.726	-0.692	-23.30	-25.46
	= total					21.77
	absolute deviation from average					0.686
rates up-down	+ income	13.9	13.4	13.0	12.6	52.9
	+ float	-0.131	-5.187			-5.319
	+ bond	-0.754	-0.726	-0.705	-24.16	-26.34
	= total					21.22
	absolute deviation from average					0.140
rates down-up	+ income	13.5	13.3	12.9	12.5	52.1
	+ float	-0.129	-5.093			-5.222
	+ bond	-0.740	-0.726	-0.705	-24.16	-26.33
	= total					20.96
	absolute deviation from average					0.128
rates down-down	+ income	13.5	13.2	13.0	12.8	52.5
	+ float	-0.129	-5.093			-5.222
	+ bond	-0.740	-0.726	-0.718	-25.06	-27.25
	= total					20.39
	absolute deviation from average					0.698
average of	totals					21.08
	absolute deviations from average					0.413

Fixed cashflows subsequent to year end will have higher values in the low-rate scenarios, and vice versa. High rate scenarios result in less costly debt and less valuable income flows (through discounting), while low rate scenarios provide opposite effects.

Income is higher in high rate scenarios than in low ones. This rate-income link follows our business cycle-inducement assumption. For year-end and beyond, high rates result not only in higher income, but also in higher discount rates. The year-end date value implications of higher rates may be positive or negative.

Based on our example assumptions, high rates raise future income and lower the net cost of debt more than they discount future income values. This result is driven by the relatively high proportion of fixed rate debt and the (assumed) positive relationship between rates and income. The operation's value is highest when rates go up in both periods, and lowest when rates decline. The impacts of lower rates are opposite to those caused by higher rates.

To further illustrate our analysis of the four scenarios, we first highlight the time 0.5 income flows. If rates rise relative to the half year maturity futures contract rate, then income is $13.4 million. The lower rate scenario produces slower growth and generates $0.1 million less income, only $13.3 million. Additionally, the high rate scenario generates more year-end value, $13.9 million ($13.4 million plus six months of interest at the annualized 7.856%). The initial rate decline scenario generates only $13.5 million of year-end value ($13.3 million invested at 4.180% annualized).

Across rate scenarios, year end (time 1.0) income flows differ by roughly $100,000. The highest year-end income follows two up rate movements ($13.5 million), while the lowest year-end income follows two down rate moves ($13.2 million). Income flows subsequent to year end are assumed to remain at their year-end values. However, the values of these subsequent income streams must be discounted back to year end. The discounted year-end values of time 1.5 and time 2.0 income are less valuable in high rate scenarios.

In all scenarios, the $5 million floating rate debt payments are indexed off prevailing six month rates. The first floating rate payment is at the initial six month rate and is grossed up to a year-end value by the realized time 0.5 forward (0.5 to 1.0) rates. The second six month floating rate payment is set by the same rates. As floating rate debt is worth par on reset dates, the prinicpal is deemed to be repaid on the year-end valuation date.

Fixed rate debt interest and principal are carried forward and back to year-end just as the income payments are. Therefore, fixed interest costs prior to year-end are higher following an initial up-rate scenario. Since fixed debt payments subsequent to year end are discounted at high rates when rates rise, their associated cost is lower.

To evaluate the riskiness of the domestic operation, we minimize the average absolute deviation of operation values across scenarios. This criterion is consistent with most corporations' risk management objectives. Although the criterion is stated in value terms, the same analysis may be used to minimize variation in accounting earnings, balance sheet equity or other values. We now consider how to lower the identified year-end value deviations.

Managing the Domestic Operation's Interest Rate Risk

In Exhibit 3, the average corporate value deviation is $412,791. These deviations are positive in high rate scenarios and negative in low rate scenarios. A simple way to reduce this variation is to lower the amount of fixed rate payments. This reduction can be made in two ways. First, if the debt has not been issued, only $10 million of fixed rate debt should be issued. Under this alternative, $20 million of floating rate debt would be issued instead of the original $5 million. However, if the debt has been issued, a $15 million pay floating-receive fixed interest rate swap would have roughly the same effect. In either case, average variation decreases to only $8,600. The resultant value outcomes are the following:

Rate Scenario -	up-up	up-down	down-up	down-down
Associated Value -	21.087	21.072	21.087	21.068

The fixed to floating debt structure adjustment limits the domestic operation's year-end value variation. Thus, the domestic operation risks for our corporation are relatively easy to hedge. However, this outcome does not hold in many situations. Often, we need more finely directed strategies to manage value deviations.

In addition to increasing the floating rate portion of our debt, finer strategies can further reduce the year-end value variation risk. In our example, a small risk trade-off still exists between the higher value up-up and down-up scenarios vs. the up-down and down-down domestic rate scenarios, even after adjusting the fix-float financing mix. Further risk reduction requires other derivative-based techniques. These techniques link our scenario-based risk management approach to fundamental derivatives valuation methods.

Given our four rate scenarios, we form composite positions of the underlying one, two, three and four period discount bonds. The cashflows of these portfolios are derivatives of the traded bond cashflows. The most basic possible derivatives are those that pay one dollar in one scenario only.

We create and price these basic derivatives as follows:

Exhibit 4

Time 0.0 Basic Derivative Composition

		scenario specific derivative security components			
discount bond maturity	$100 face value cost	up-up (cap)	up-down (knock-up)	down-up (knock-down)	down-down (floor)
0.5	97.528	0.000	0.529	-0.529	0.000
1.0	94.882	15.205	-15.744	-13.841	14.390
1.5	92.082	-31.056	31.056	29.935	-29.935
2.0	89.144	15.897	-15.897	-15.608	15.608
derivative security cost		0.235	0.235	0.239	0.239

To interpret this derivative security construction and valuation matrix, we consider the creation of a one dollar claim to be paid at year end only if rates increase in the first half-year and decrease in the second-half year (the knock-up derivative). We need to transact the following amounts of discount bonds:

buy 52.9% of the half-year maturity costing $51.606

sell 1,574.4% of the one-year maturity receiving $1,493.867,

buy 3,105.6% of the one and a half-year maturity costing $2,859.662, and

sell 1,589.7% of the two year maturity receiving $1,417.167.

After accounting for rounding error, this contingent one dollar payout costs $0.235. The other basic derivatives are created analogously, and their associated components and costs are also reported in Exhibit 4.

Conceptually, these basic derivatives correspond to two well-known interest rate derivatives, and two less-used derivative variants. The up-up basic scenario security serves as an interest rate cap; it's value is higher following rate increases. Analogously, the down-down basic scenario security serves as an interest rate floor.

The other two basic securities are "exotic" derivatives because their payouts are dependent on the interest rate path. Both of these path-dependent derivatives have "knock" features. Rates must knock into a particular rate level before value may be derived from subsequent rate movements.

Returning to our rate risk management exercise, we can use the knock derivatives to eliminate our residual value variation. We sell $7,500 face value of the cap (up -up) derivative to finance $7,500 face value of the knock-up (up-down) derivative. Since the costs of these derivatives are both $1,763 ($0.235 per dollar), the net transaction is zero cost. Analogously, we sell $9,800 face value of the knock-down (down-up) derivative to finance the same amount of the floor (down-down) derivative. Again, the per unit cost of each derivative equals $2,303 ($0.239 per dollar), so that the net transaction cost is zero.

Following these two zero cost transactions, our net exposures differ by less than $2,000 across scenarios. The scenarios in which rates initially rise display about $2,000 more value than the scenarios in which rates initially fall. This remaining value variation may be eliminated by selling $2,000 face value of the cap (up-up) and knock-up (up-down) derivatives to finance the same face amount of knock-down (down-up) and floor (down-down) derivative purchases.

Finally, to validate our claim that interest rate scenario analysis is consistent with derivatives pricing theory, we value the operation's equity. To calculate this value, we multiply each year-end scenario's net cashflows by the associated scenario basic derivative price. Except for truncation rounding error, the value of the net domestic operation cashflows (stated in Exhibit 3) is $20 million. This value matches the assumed equity value.

Our discussion of the domestic operating environment illustrates two important developments. First, we largely eliminate domestic rate risk by adjusting our financing structure toward floating rate debt. Second, we use the domestic case to break down the risk management exercise into one of scenario identification and associated derivatives-based hedging and valuation. We use the same techniques in the more complicated international case.

The International Interest Rate and Currency Situation

The international operating environment is complicated by additional foreign interest rate and currency risks. The evolution of foreign interest rates from their intial forward rate levels is analogous to the domestic case. Foreign currency values will evolve similarly. The likely ranges of foreign rate and currency prices movements will be related to their standard deviations. Over the 1981-1993 period, historical annualized estimates of the U.K. rate standard deviation and the U.S. dollar-U.K. pound exchange rate standard deviation are 2.4% and 12.54%, respectively.

To fully characterize rate and currency movements, we must also define the relationships that exist between domestic rates, foreign rates and currency. Just as standard deviations are intuitively linked to likely outcome ranges, correlations have an intuitive interpretation. Our interest is in the direction of interest rate and currency movements rather than their magnitude. Specifically, we are interested in how the direction of movement in one rate or currency is related to the direction of movement in another rate or currency.

In our international example, we can study what interest rate movements in the U.S. tell us about U.K. rate movements. To normalize this question, we use the number ten. That is, if ten times out of ten U.K. rates rise with U.S. rates, then the sign of U.S. rate movement is perfectly informative and provides positive news about U.K. rate direction. Similarly, if ten times out of ten U.K. rates fall with a rise in U.S. rates, then the sign of U.S. rate movement is again perfectly informative with regard to U.K. rates, although with negative news. However, if five times out of ten, U.K. rates rise with U.S. rates, then the sign of U.S. rate movement is noninformative with regard to U.K. rates. The other five times out of ten U.K. rates fall as U.S. rates rise.

Correlations are consistent with this count-based interpretation of association. If two rates or currencies rise together ten out of ten times, then the association is perfect, positive, and defined as one. If one rate or currency rises and the other one always falls, the association is again perfect, and defined as minus one. If a rise in one rate or currency implies that the other has equal probability of an up or down movement, then an association is absent and the correlation is defined as zero. The zero correlation has no count bias, whereas the positive and negative one correlations are one hundred percent biased.

Analogously, other correlations may be defined by their count bias:

Positive count bias	0	1	2	3	4	5	6	7	8	9	10
Correlation	-1.0	-0.8	-0.6	-0.4	-0.2	0.0	0.2	0.4	0.6	0.8	1.0

Interest rate and currency correlations should be related by their fundamentals. It is reasonable to assume that interest rates are positively linked across countries. Both levels of real activity and inflation drive this positive correlation. In fact, such a correlation was manifest across U.S. and U.K. interest rates over the the 1981 to 1993 period (correlation estimate 0.19). This estimate means that roughly six times out of ten an increase in U.S. rates was associated with a U.K. rate increase. Although it is feasible for two countries' rates to be negatively related (different real activity or inflation cycles), a positive rate association existed across the U.S. and U.K.

Currency and rate correlations are more difficult to interpret than rate-rate correlations. The reasons for this difficulty are found in the different effects that real activity and inflation have on rates and currency values. While higher real activity should raise interest rates, it may either raise currency values (through a relative productivity and foreign investment-led capital inflow) or lower them (through rising imports). Similarly, higher rates may be driven by inflation, which should lower currency values. However, inflation-driven rate increases may force monetary tightening and/or central bank foreign exchange market intervention. These phenonmena all yield conflicting rate-currency correlation implications.

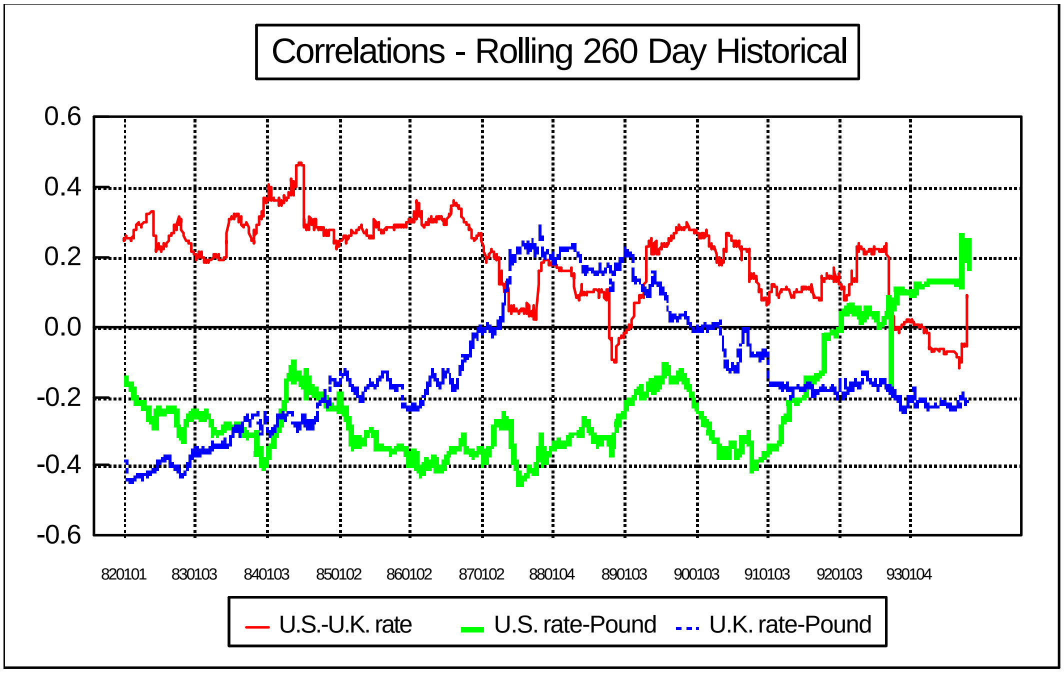
Therefore, we are left with historical evidence and judgement to interpret our rate and currency correlations. Based on the 1981-1993 period, the U.S. rate-British pound correlation was -0.15. Higher U.S. rates were associated with pound appreciations only 4.25 times out of ten. This correlation estimate is consistent with both the rising relative productivity-increased foreign investment and strict U.S. monetary policy interpretations.

Over the same period, the U.K. rate-British pound correlation was -0.18. The pound was biased toward falling in value with U.K. rate increases. Roughly four times out of ten, the pound fell in value when U.K. rates rose, and vice versa. This correlation estimate is consistent with both the falling relative productivity-decreased foreign investment and loose U.K. monetary policy interpretations (the opposite of the U.S. rate-pound correlation interpretation).

To further document the U.S. rate, U.K. rate and pound currency correlation phenomenon, Figure 1 graphs a rolling set of correlation estimates. These estimates are based on a series of one year observation intervals. To generate each estimate, these observation intervals are advanced forward each business day.

In Figure 1, we see that cross-rate correlations are the most stable, while rate-pound correlations are more variable. In fact, the rate-pound correlation estimates switch sign over the observation period. As noted above, such switches are feasible and are driven by changing rate and currency fundamentals.

Figure 1



To create a benchmark international scenario set, we use the 1981 -1993 period standard deviation and correlation estimates. In generating these scenarios, the foreign interest rates and the currency value evolve in the same manner as domestic interest rates. Current rate or currency values are augmented by a small drift term and a standard deviation-adjusted up or down movement. For the foreign rate and currency values, we induce the U.S. rate assocation by adding a correlation-weighted component of the U.S. rate movement to the rate or currency change. We induce the foreign rate-currency assocation by adding a correlation-weighted component of the foreign rate change to the currency movement.

To calibrate our benchmark, we use the initial foreign term structure, and a British pound value of $1.40:

Exhibit 5
Initial Foreign Term Structure[6]

time 0.0	years	0.0 to 0.5	0.0 to 1.0	0.0 to 1.5	0.0 to 2.0
discount rate		5.993	6.483	6.647	6.973
bond yield			6.581	6.747	7.070
	years	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0
forward rate		5.993	6.974	6.974	7.951
	years	0.0 to 0.5	0.0 to 1.0	0.0 to 1.5	0.0 to 2.0
forward currency		1.3931	1.3829	1.3761	1.3661

6 The discount rates are annual and continuously compounded, the bond yields are stated on an actual-365 day semi-annual basis, and the forward rates are also annual and continuously compounded.

Based on three sources of uncertainty, many scenario sets are possible. As with domestic interest rate scenarios, we create the simplest foreign interest rate and currency scenario set. However, we must insure that scenario evolution is consistent with the estimated standard deviations and correlations. To do this, one of four equally probable scenarios (A, B, C or D) must evolve from any past scenario.[7] Exhibit 6 presents the integrated domestic rate, foreign rate and currency scenario sets.

At both times 0.5 and 1.0, the basic scenario set is consistent with the orignial domestic rate scenarios. At time 0.5, there are only two possible domestic rate outcomes. Increased domestic rates occur in augmented scenarios A and B, while falling domestic rates occur in scenarios C and D.

At time 1.0, rates and currency values must evolve from the time 0.5 scenarios. For example, sequential increases in domestic rates (up-up domestic rate scenario) must evolve from time 0.5 up rate scenarios (A and B). At time 0.5, rates only increase if scenarios A and B occur. Therefore, the up-up domestic rate scenario occurs in time 1.0 compound scenarios AA, AB, BA and BB.

Analogously, the up-down domestic rate scenarios are AC, AD, BC and BD, the down-up scenarios are CA, CD, CB, DB, and the down-down rate scenarios are CC, CD, DC and DD. These scenarios are also indicated by the plus and minus numbers in parentheses: the up-up scenarios are plus 1.4 rate standard deviations, the stable scenarios are plus or minus zero standard deviations, and the down-down scenarios are minus 1.4 rate standard deviations.

The foreign rate and currency scenarios evolve analogously. At time 0.5, both the foreign rate and currency value change. However, the scenarios in which up or down moves occur differ both from the domestic rate case, and from each other. Foreign rates rise in scenarios A and D, but fall in scenarios B and C. The foreign currency value rises in scenarios A and C and falls in scenarios B and D. To induce appropriate correlations, we must insure that both rates and the currency do not rise and fall in all of the same scenarios.

At time 1.0, both the foreign rates and the currency have four up outcomes, four down outcomes and eight (relatively) stable outcomes. This relative count, again, matches the domestic rate scenario case. Foreign rate up scenarios are AA, AD, DA and DD, while the down scenarios are BB, BC, CB, and CC. Foreign currency up scenarios are AA, AC, CA and CC, and the down scenarios are BB, BD, BD and DD.

With regard to correlations, the time 1.0 outcomes are in line with the assumed correlation estimates. For the positive (0.19) U.S.-U.K. rate correlation, six scenarios have joint rate movements of the same sign and only two have opposite rate movements (while the others are stable). For the negative (-0.15) U.S. rate-British pound correlation, only two scenarios have joint movements of the same sign and five have opposite movements. The negative (-0.19) U.K. rate-British pound correlation has six scenarios with opposite movements and only two movements of the same sign.

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[7] The approach is developed in Amin-Bodurtha (1994).

Exhibit 6
Integrated Domestic Rate, Foreign Rate and Currency Scenarios

	Time 0.5 Scenario	A	B	C	D
	Domestic Rate	7.347 (+1.0)	7.347 (+1.0)	3.670 (-1.0)	3.670 (-1.0)
	Foreign Rate	8.999 (+1.2)	5.667 (-0.8)	5.022 (-1.2)	8.355 (+0.8)
	Currency	1.473 (+0.9)	1.273 (-1.4)	1.554 (+1.8)	1.272 (-1.4)

Time 0.5 Scenario	Time 1.0 Scenario	A	B	C	D
A	Domestic Rate	9.703 (+1.4)	9.703 (+1.4)	6.026 (-0.0)	6.026 (-0.0)
	Foreign Rate	11.040 (+1.7)	7.707 (0.3)	7.062 (0.0)	10.395 (+1.4)
	Currency	1.544 (+1.3)	1.335 (0.4)	1.629 (+2.0)	1.334 (-0.4)
B	Domestic Rate	9.703 (+1.4)	9.703 (+1.4)	6.026 (-0.0)	6.026 (-0.0)
	Foreign Rate	7.707 (+0.3)	4.375 (-1.1)	3.730 (-1.4)	7.062 (+0.0)
	Currency	1.357 (-0.2)	1.174 (-1.7)	1.432 (+0.4)	1.173 (-1.7)
C	Domestic Rate	6.026 (+0.0)	6.026 (+0.0)	2.349 (-1.4)	2.349 (-1.4)
	Foreign Rate	7.062 (+0.0)	3.730 (-1.1)	3.085 (-1.7)	6.418 (-0.3)
	Currency	1.632 (+2.0)	1.411 (+0.2)	1.722 (+2.7)	1.410 (+0.2)
D	Domestic Rate	6.026 (+0.0)	6.026 (+0.0)	2.349 (-1.4)	2.349 (-1.4)
	Foreign Rate	10.395 (+1.4)	7.062 (+0.0)	6.418 (-0.3)	9.750 (+1.1)
	Currency	1.314 (-0.6)	1.136 (-2.0)	1.387 (+0.0)	1.135 (-2.0)

We conclude that the coarse example scenario set is consistent with our volatility and correlation estimates.[8] If either these estimates or our intuition about the likelihood of these estimates changes, our scenario set will change as well. Such changes will generate an alternative scenario set. To the extent that there is significant uncertainty about the appropriate rate risk parameter estimates, multiple scenario sets should be generated with risk minimization alternatives evaluated across them. We now analyze and manage the foreign and combined operations joint domestic rate, foreign rate and currency risks. First, we treat the foreign operation separately. Then, we integrate our treatment of both domestic and foreign operations.

Managing the Foreign Operation's Interest Rate and Currency Risks

Like the domestic operation, foreign operation output is linked to foreign interest rate levels. We assume that higher rates are associated with an improving foreign business

8 Note that the one year expected future currency spot price is 1.3828, and is not equal to the 1.3829 one-year forward currency price. Instead, the expected spot price equals the futures price. This situation occurs because forward and futures currency prices differ in the presence of interest rate risk.

cycle and higher income. The exact correspondence is defined as it was for the domestic operation, albeit based on foreign rate to foreign futures rate differences.

Furthermore, we assume that the foreign operation is subject to exchange rate risk in its home market. This currency risk is in addition to the currency risk that the parent faces on its foreign operation's income repatriation. The assumed income-currency link is a negative one, based on an assumption of declining international competitiveness in a strong currency country. Realized currency values above initial-associated maturity currency futures prices are assumed to reduce income by raising relative foreign costs and lowering sales. On the contrary, the domestic operation's income is assumed to be insensitive to currency levels.

Foreign operation income is complicated by its relation to both foreign interest rate and currency price levels. Therefore, we do not develop our discussion of the foreign operation's values. Instead, we provide summary numbers, highlighting the important rate and currency effects. Exhibit 7 presents these pound outcomes.

The fundamental income, rate and principal repayments which underlie the composite year-end values are calculated just as they were in the domestic operation case. However, in the foreign operation case, there are more unique foreign operation scenarios than there are domestic operation scenarios. The reason for this scenario expansion is the foreign operation's sensitivity to both interest rate and currency levels. Nevertheless, the composite value deviation minimization criterion that was used for the domestic case also applies to the foreign operation.

The average value deviation across scenarios is 836,570 pounds. To lower this variation, we consider adjustments in our 3.57 million pound floating rate debt and 17.86 million pound fixed rate debt ($5 million and $25 million, respectively). As noted, a simple examination of the income variability indicates that it is much more disperse than in the U.S. operation case. Were the foreign operation's pound income insensitive to currency risk, then its risk could be managed in roughly the same way that the U.S. operation's risk was. We would simply shift 10.71 million pounds ($15 million) of the liability to floating rate debt.

Despite the complications that currency risk brings to the foreign operation, we still evaluate how much debt to float and fix. The minimum year-end value variation is attained with all 21.43 pounds of debt financed at floating rates. With this short financing tenor, value variation is reduced to 642,316 pounds. This move to floating rate debt largely immunizes the foreign operation from foreign interest rate risk. However, foreign currency risk is still manifest. Exhibit 8 reports the risk exposure with all financing at floating rates.

For the foreign operation, the scenarios which manifest high variation are those linked with significant exchange rate moves [positive variation (low pound) - BB, BD, DB and DD - and negative variation (high pound) - AA, AC, CA and CC]. Comparing Exhibit 8 exposures with the exposures of Exhibit 7, we see that the large scenario value deviations of Exhibit 7 have been reduced in Exhibit 8. The shift to floating-rate financing minimizes the the variation in the scenarios where foreign interest rate and currency movements combine to create substantial value variation (CC, DB and DD).

Exhibit 7
Foreign Operation Year End Pound Cashflows
(3.57 million floating rate and 17.86 million fixed rate debt)

Time 0.5 Scenario	Scenario	Time 1.0 A	B	C	D
A	Income	37.3	38.5	37.2	38.3
	Interest & Liability	-22.2	-22.8	-22.9	-22.3
	Total	15.07	15.74	14.27	16.02
	absolute deviation from average	0.293	0.371	1.097	0.658
B	Income	38.1	39.4	38.0	39.2
	Interest & Liability	-22.7	-23.3	-23.4	-22.8
	Total	15.44	16.11	14.63	16.40
	absolute deviation from average	0.077	0.742	0.738	1.034
C	Income	36.8	38.1	36.7	37.9
	Interest & Liability	-22.8	-23.4	-23.5	-22.9
	Total	14.05	14.70	13.22	15.00
	absolute deviation from average	1.319	0.665	2.150	0.362
D	Income	38.4	39.6	38.3	39.5
	Interest & Liability	-22.3	-22.9	-23.0	-22.4
	Total	16.09	16.77	15.30	17.05
	absolute deviation from average	0.729	1.400	0.068	1.682
average of	totals				15.365
	absolute deviations from average				0.837

Since the remaining risk in the foreign operation's value is currency driven, a simple forward transaction may significantly lower the exhibited value variation. The foreign operation's pound-denominated income is negatively impacted by higher pound values. Therefore, the appropriate ***economic*** hedge (from the foreign subsidiary's perspective) is to buy pounds forward. The average currency risk-induced variation is about 1.1 million pounds, and the absolute value of pound forward speculative profits are about 150,000 pounds on 1 million pounds. Buying 7.5 million pounds forward (1.1/0.15) significantly reduces the average deviation to 215,872 pounds. Lowering the forward purchases slightly, to 6.4 million pounds, provides the "optimal" currency hedge, with only 186,822 pounds of average value deviation.

Exhibit 8
Foreign Operation Year End Pound Cashflows
(21.37 million floating rate debt)

Time 0.5 Scenario	Scenario	Time 1.0 A	B	C	D
A	Total	14.19	15.42	14.06	15.25
	absolute deviation from average	1.162	0.071	1.285	0.102
B	Total	15.43	16.68	15.32	16.50
	absolute deviation from average	0.083	1.336	0.028	1.153
C	Total	14.21	15.45	14.08	15.28
	absolute deviation from average	1.141	0.104	1.265	0.072
D	Total	15.38	16.62	15.26	16.44
	absolute deviation from average	0.028	1.272	0.084	1.091
average	total average				15.348
	absolute deviation from average				0.642

For the foreign operation, we find that moving completely to floating-rate debt and buying 6.4 million pounds forward reduces risk exposures by about two-thirds. As suggested in our treatment of the domestic operations dollar risk management, further foriegn operation risk reduction entails transactions in more basic derivative securities. However, we do not develop this exercise further. Instead, we discuss the valuation of the basic securities. We then address the parent corporation's integrated risk management problem. In this treatment, we use the full set of basic derivative securities, highlighting the relationship between the two subsidiary operations' local hedging transactions and the global hedging operations of the parent.

Basic Interest Rate and Currency Derivatives

Exhibit 4 reports a method for constructing four basic domestic interest rate derivatives and their associated costs. These derivatives each pay out one dollar in only one of the four domestic interest rate scenarios. The derivatives help eliminate domestic rate-induced value variation.

For the international case, we have not one source of risk, but three sources. In our example, these risks generate 16 different year-end scenarios. To fully manage the risks across these scenarios, we require 16 basic derivative securities. Just as the domestic rate-linked basic derivatives were created from portfolios of domestic bonds, these broader cross-country basic derivatives can be constructed from particular portfolios of domestic and foreign bonds. However, in a broader example with more time periods and scenarios, such transactions become more and more difficult to achieve. The main sources of this difficulty are the relatively finite number of liquidly traded foreign and domestic bonds and the associated costs of buying and selling them.

Therefore, we create our basic cross-country derivatives by dynamic trading strategies. To ensure that the basic deriviatives pay out in only one scenario, these strategies require transactions in every period. In practice, investment banks effectively create such basic securities as one of their services. Alternatively, the corporate risk manager may choose to "in-source" construction of these basic derivatives and other hedge components. This out-source vs. in-source question is fundamental for corporate financial managers. Our discussion highlights the methods and intuition behind a dynamic hedging process.

Building the cross-country basic derivatives directly follows the logic of the creation of the basic domestic rate derivatives. Exhibit 9 shows both the components of the cross-country derivatives and their costs (just as Exhibit 4 did for the domestic case):

Exhibit 9

Time 0.0 Cross-Country Basic Derivative Composition

discount bond currency and maturity	100 currency units face value cost	time 0.5 scenario specific derivative security components A	B	C	D
domestic 0.5	$97.528	0.050	0.137	-0.081	-0.095
domestic 2.0	$89.144	-0.084	-0.114	0.060	0.138
foreign 0.5	$135.867	.0.104	-0.104	-0.038	0.038
foreign 2.0	$121.776	-0.093	0.093	0.066	-0.066
derivative security cost		0.244	0.244	0.244	0.244

The strategies in Exhibit 9 are easily interpreted. Consider the components and cost of the basic derivative associated with scenario A. In this scenario, domestic rates, foreign rates and currency value all increase (about one standard deviation). For our corporation, this scenario provides two positive income factors (the rate increases), and one mixed factor (the currency increase). Therefore, scenario A is one of positive value deviation.

To trade this value against another negative deviation (e.g. scenario C), we "sell" the components that make up scenario A's basic derivative. That is, we borrow $5 (5% of $100) and 10.4 pounds (10.4% of 100 pounds) for six months. We then invest these funds in $11.4 of the dollar two year maturity discount bond and 9.3 pounds in the two year maturity pound discount bond, retaining $0.244. To shift our risk, we use the residual funds to purchase a basic derivative that is assciated with a scenario in which we are doing relatively less well (e.g., scenario C).

These hedging transactions provide us with the ability to eliminate time 0.5 risks, but not year-end (time 1.0) risks. To provide year-end basic derivatives, we use the time 0.5 basic derivatives and another set of hedging trades. These transactions are undertaken at time 0.5, and are contingent on the time 0.5 basic derivatives. In this case, we buy a time 0.5 scenario-specific basic derivative and use the funds it generates to fund another time 0.5 to 1.0 basic derivative. The full set of these combined transactions creates the 16 scenario year-end basic derivative set.

To create basic derivatives paying one dollar in scenarios AA, AB, AC and AD, we first buy basic derivative A. However, we do not know how much of this derivative to buy without calculating the hedging costs contingent on scenario A.

If we reach scenario A (rising domestic rates, foreign rates and currency price), then we know the associated bond values. Given these contingent bond values, we may again develop the composition and costs of the four contingent basic derivatives. Exhibit 10 depicts this exercise:

Exhibit 10

Time 0.5 Cross-Country Basic Derivatives Composition

time 0.5 discount bond currency and maturity	100 currency units face value cost	from time 0.5 scenario A to time 1.0 scenario specific derivative security components AA	AB	AC	AD
domestic. 1.0	$96.393	0.088	0.189	-0.109	-0.158
domestic 2.0	$88.884	-0.125	-0.170	0.089	0.206
foreign 1.0	$140.782	.0.139	-0.139	-0.065	0.065
foreign 2.0	$128.001	-0.131	0.131	0.092	-0.093
time 0.5 scenario A derivative security cost		0.241	0.241	0.241	0.241
time 0.0 derivative security cost (0.241*scenario A derivative cost)		0.0588	0.0588	0.0588	0.0588

The format of Exhibit 10 follows that of Exhibit 9. Additionally, we use the same method to interpret basic derivative components and costs. However, the last row of Exhibit 10 documents the key calculation for the cost of year-end basic derivatives. The calculation is straight forward, and highlights the dynamic method of creating these derivatives.

To generate one dollar in scenario AA, we require $0.241 at time 0.5, in the event that scenario A occurs. To provide these funds, we either purchase 24.1% of the scenario A-associated basic derivative or create the equivalent portfolio. Through either transaction, the total cost is the percentage of the basic security purchased multiplied by it's time 0.0 price. In our example, this cost is $0.0588 (0.241*$0.244).

All of 16 of the year-end basic derivatives can be created using the same method. To create basic derivatives AA, AB, AC and AD, we buy a fraction of basic derivative A and use the resultant funds to purchase the subsequent scenario basic security. Analogously, we work with basic derivative B to create subsequent securities BA, BB, BC and BD. The C and D scenario basic derivatives are used to create the remaining basic derivatives.

Exhibit 11 reports the costs of these derivatives:

Exhibit 11
Time 0.0 Cross-Country Basic Derivative Security Costs

Time 0.5	Time 1.0			
Scenario	A	B	C	D
A	0.588	0.588	0.588	0.588
B	0.588	0.588	0.588	0.588
C	0.598	0.598	0.598	0.598
D	0.598	0.598	0.598	0.598

These basic derivatives provide insurance against the associated scenario outcomes, listed in Exhibits 3 and 5. With these derivatives, we address the parent corporation's full risk management problem.

Integrated Interest Rate and Currency Risk Management

With basic derivatives available, the parent corporation's integrated risk management problem can be solved. However, before solving this problem, we must first define which risks are managed in the subsidiaries, and which risks are managed centrally. As is often the case in practice, we assume that the subsidiary operations have managed their local interest rate risk, but have not addressed their currency exposures beyond that. Therefore, the parent treasury confronts a domestic operation with $20 million in floating rate debt and $10 million in fixed rate debt, and a foreign operation with $30 million (21.37 million pounds) in floating rate debt. The parent corporation's initial scenarios are presented in Exhibit 12

The first step to lower the $987,288 average value deviation is to analyze alternative financing maturities. Our best solution is to issue $20.385 million floating, $5.367 million fixed, $20.356 million in pounds floating, and $13.894 million in pounds fixed. This financing mix results in an average value deviation of $706,418.

Relative to the delegated subsidiary operation financing strategies, total domestic debt should be reduced, and foreign fixed rate debt should be issued. However, we assume this debt is already issued. Thus, we use swap transactions to create the desired liability mix. The necessary swap transactions are three:

receive $4.633 million dollars floating and pay pounds fixed,
receive $9.261 million pounds floating and pay pounds fixed, and
receive $0.385 million pounds floating and pay dollars floating.

Exhibit 12
Parent Corporation Year-End Dollar Cashflows

Time 0.5 Scenario		Time 1.0 A	B	C	D
A	cashflow	42.14	42.95	42.26	42.70
	deviation	-0.019	0.797	0.105	0.545
B	cashflow	41.30	41.77	41.54	41.53
	deviation	-0.852	-0.387	-0.617	-0.622
C	cashflow	43.40	44.20	43.55	43.93
	deviation	1.238	2.047	1.393	1.774
D	cashflow	40.57	41.06	40.77	40.83
	deviation	-1.587	-1.101	-1.384	-1.331
Average cashflow					42.16
Average deviation from average					0.987

With this revised financing mix, we use the basic derivatives to lower specific value deviations. The largest relative deviations are manifest across scenarios CD and DC. Scenario CD provides $43.843 in value, while scenario DC provides only $40.925 in value. The difference is driven by the slightly higher exchange rate that results in scenario DC.

Since average value across scenarios is $42.157 million, we sell the CD-associated basic derivative to finance a $1.231 million face value purchase of the DC-associated derivative. This transaction brings the DC-scenario value closer to the average, while the CD-scenario remains slightly higher. From Exhibit 11, we know that the costs of the CD-basic derivative and DC-basic derivative are the same. Therefore, selling one and buying the other (in equal quantity) is costless. Following this transaction, the average value deviation is reduced to $552,499, or 22 percent less than the deviation that existed without centralized hedging activity.

Similarly, we can identify other relative value deviations across scenarios, and buy the low and sell the high. In this way, we use all of the basic derivatives to completely eliminate value deviation. Of course, this activity requires 16 transactions

A useful alternative to creating the full basic derivatives set is based on the logic behind the dynamic creation of these derivatives. Based on our example assumptions, we can transact in the underlying bond markets and attain the same outcomes that we would by trading the basic derivatives.

We present this alternative in the context of Exhibit 12. In this alternative, the parent has not made any adjustments to the subsidiary operations' financing strategies. Exhibit 13 depicts the dynamic hedging strategy that eliminates all value deviations.

Exhibit 13

discount bond currency and maturity	time 0.0	At time 0.5 Derivative Security Components A	B	C	D
domestic. 1.0	0.066	-0.017	0.082	0.128	-0.126
domestic 2.0	0.049	0.029	-0.068	-0.095	0.183
foreign 1.0	0.013	-0.036	-0.062	0.061	0.051
foreign 2.0	-0.104	-0.032	0.055	-0.104	-0.087
cost	-0.0011	-0.0839	0.1456	-0.3861	0.3233

At time 0.0, we undertake our first hedge transaction: we invest both short-term and long-term in the domestic currency, invest short-term in the foreign currency, borrow a relatively large amount long-term in the foreign currency and receive a small amount of cash. In the next period (time 0.5), this position generates sufficient funds in each scenario to undertake the subsequent hedging transcation.

If at time 0.5, scenario A is realized, then we will transact as indicated in Exhibit 13: borrow $17,000 short-term, invest $29,000 long-term, borrow $3,600 of pounds short-term, borrow $3,200 of pounds long-term, and have $8,390 in cash reserve for subsequent (time 1.0) losses. Realization of another scenario entails a similar transaction.

Compared to the other risk management alternatives, this last one is the simplest. Four transactions are required in each of the two periods. Following this strategy, year-end values of $42.157 million are realized in all scenarios.

Other Considerations

To conclude, we outline some alternatives to our analysis, as well as provide some extensions and caveats. Specifically, we consider the following topics: alternative risk management critieria, longer time and/or shorter time intervals, changing risk parameters and the issue of trading and positioning for profits.

Alternative Risk Management Criteria

In our analysis, we have focused on minimizing the subsidiaries' and parent's year-end value fluctuations. However, this criterion is not exclusive. Other constraints may be introduced on ***any*** scenario outcome or groups of these outcomes.

Other relevant risk targets could be income statement- and/or balance sheet-related. These requirements are (usually) enforced across time periods, scenarios within a time period and mixed time-scenario outcomes.

A clear application of an alternative criterion is one that insures debt interest and principal repayment. This insurance and its implicit cost are determined by imposing payment constraints in each scenario. These constraints require that available cash be sufficient to meet the debt-related payments.

Capital adequacy requirements can be met in the same way. The relevant market and/or book values of equity can be constrained to stay above certain absolute or percentage liability values.

Alternative Time Periods

Our approach obviously extends to both finer time partitions (e.g. monthly or quarterly value dates), longer time periods and more scenarios in each period. These extensions require only transactions at each date of the type defined in our examples for current, half-year and year-end dates. With finer time partitions, transactions could be evaluated and made at each successive evaluation date. Longer time periods add evaluation times (subsequent half-years).

More scenarios in a subsequent time period permit evaluation of a broader range of outcomes in that next period. Our analysis has treated rate and currency scenarios of three predominant types: up, down and stable. This scenario set can be extended to include significant (> 2.0 standard deviations) up and down moves. This adjustment may be necessary if cashflows are more significantly and differentially affected in such cases.

Changing Risk Parameters

In practice, all of the risk-related parameter inputs (standard deviations and correlations) change. However, our approach is built on an assumption that these changes don't occur. Nevertheless, our approach is useful because it embodies the parameters that do change. Therefore, we can use our model to evaluate risk management strategies in alternative scenarios. Our modeling approach permits sensitivity analysis over alternative business risk environments.

Such sensitivity analysis is common in all valuation methods. Internal rate of return (IRR) and/or net present value (NPV) analyses are carried out under certain fixed expected cashflow and cost of capital assumptions. Since these quantities are not fixed, we must evaluate the sensitivity of our results to feasible changes in our cashflow and capital cost assumptions. This second-stage sensitivity analysis validates our NPV- and IRR-based decisions.

In our context, the same sensitivity testing must be done with regard to the standard deviation and correlation inputs. The necessity of conducting this sensitivity analysis motivates our extended discussion of standard deviation and correlation intuition. Our intuition about likely change in the fundamentals which underlie interest rate and currency movements is translated into alternative parameter values, with associated outcomes. Furthermore, using current bond, bill, swap, currency and associated option values, we can develop an implicit market view on the appropriate values of these parameters.

This evaluation requires extension of well-known implicit option volatility calculations to the multiple interest rate and currency case. Implicit correlation estimation is a new and important element for the type of analysis that we advocate.

Trading for Profits

Finally, there is the issue of trading or positioning for profits. Such positioning requires views on the directions of risks (standard deviations) and the correlations across interest rates, currencies and business outcomes. These differing views may be embodied in probability assessments.

For example, if we expect rates to rise above the amount of drift implied by current market benchmarks, then our assessment of the relative likelihood of an up move is higher than those assumed under the initial valuation and risk minimization analysis. Subject to our business constraints and other conditions, opportunities and exposures arise across our scenario set, and risk-return trade-offs can be managed with the same risk management tools that have been highlighted.

With regard to volatility, higher probabilities of both up and down scenarios and lower probabilities of stable scenarios reflect a view that more volatility is likely. Such a change will increase the values of many derivatives. If our view is one of higher volatility than implied by current market benchmarks, then we will be likely to buy derivatives, and vice versa.

Analogously, probability changes permit us to differentiate our correlation view from the market consensus. Nevertheless, this exercise must be consistent and coordinated with any direction or volatility adjustments we make. To treat different direction, volatility and correlation views, it is useful and may be necessary to have more scenarios evolve at each point in time (than four). This extension to the modeling approach has been discussed above.

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