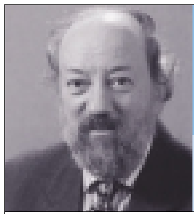

Bill Ziemba

Gambling and Investment Hedge Fund Concepts II

How to lose money in derivatives, oh and how to make it fast too

The derivatives industry deals with products in which what one party gains the other party loses – situations known as zero sum games. Hence there are bound to be large winners and large losers. The size of the gains and losses are magnified by leverage and overbetting, leading invariably to large losses when a bad scenario occurs.

Figlewski (1994) attempted to categorize derivative disasters and this column discusses and expands on that.

1. Hedge

In an ordinary hedge, one loses money on one side of the transaction in an effort to reduce risk. The correct way to evaluate the performance of a hedge is to consider all aspects of the transaction. In sophisticated hedges where one delta hedges but is a net seller of options, there is volatility (gamma) risk which could lead to losses if there is a large price move up or down. Also accounting problems can lead to losses if gains and losses on all sides of a derivatives hedge are recorded in the firm's financial statements at the same time.

2. Counterparty default

Credit risk is the fastest growing area of derivatives and a common hedge fund strategy is to be short overpriced credit default derivatives. There are lots of ways to lose on these shorts if they are not hedged properly, even if they have an edge.

3. Speculation

Derivatives have many purposes including transferring risk from those who do not wish it (hedgers) to those who do (speculators). Speculators who take naked unhedged positions take the purest bet and win or lose monies related to the size of the move of the underlying security. Bets on currencies, interest rates, bonds, or stock market moves are leading examples.

Human agency problems frequently lead to larger losses for traders who are holding losing positions that if cashed out would lead to lost jobs or bonus. Some traders will increase exposure exactly when they should reduce it in the hopes that a market turnaround will allow them to cash out with a small gain before their superiors find out about the true situation and force them to liquidate. Since the job or bonus is already lost, the trader's interests are in conflict with the firm's and huge losses may occur. Writing options which typically gain small profits most of the time is a common vehicle for this problem because the size of the position accelerates quickly as the underlying security moves in the wrong direction. Since trades between large institutions frequently are not collateralized mark-to-market large paper losses can accumulate without visible signs such as a margin call. Nick Leeson's loss betting on short puts and calls on the Nikkei is one of many such examples. The Kobe earthquake was the bad scenario that bankrupted Barings.

A proper accounting of trading success is to evaluate all gains and losses so that the extent of some current loss must be weighed against previous gains. Derivative losses should also be compared to losses on underlying securities. For example, from January 3 to June 30, 1994, 30-year T-bonds fell 13.6 per cent. Hence holders of bonds lost considerable sums as well since interest rates quickly rose very much.

Derivatives have many purposes including transferring risk from those who do not wish it (hedgers) to those who do (speculators)

4. Forced liquidation at unfavorable prices
Gap moves through stops are one such example. Portfolio insurance strategies based on selling futures during the October 19, 1987, stock market crash were unable to keep up with the rapidly declining market whose futures fell 29 per cent that day. Forced liquidation due to margin problems is made more difficult when others have similar positions and predicaments. The August 1998 problems of Long Term Capital Management in bond and other markets were more difficult because others had followed their lead with similar positions. When trouble arose, buyers were scarce and sellers were everywhere. Another example is Metallgellschaft's crude oil futures hedging losses of over $1.3 billion. They had long-term contracts to supply oil at fixed prices for several years. These commitments were hedged with long oil futures. But when spot oil prices fell rapidly, the contracts to sell oil at high prices rose in value but did not provide current cash to cover the mark-to-market futures losses. A management error led to the unwinding of the hedge near the bottom of the oil market and the disaster.

Potential problems are greater in illiquid markets. Such positions are typically long term and liquidation must be done matching sales with available buyers. Hence, forced liquidation can lead to large bid-ask spreads. Askin Capital's failure in the bond market in 1994 was exacerbated because they held very sophisticated securities which only were traded by very few counterparties who once they learned of Askin's liquidity problems and weak bargaining position further lowered their bids. They were then able to gain large liquidity premiums.

5. Misunderstanding the risk exposure
As derivative securities have become more complex, so has their full understanding. Our Nikkei put warrant trade (discussed in my last column) was successful because we did a careful analysis to fairly price the securities. In many cases, losses are the result of trading in high-risk financial instruments by unsophisticated investors. Law suits have arisen by such investors attempting to recover some of their losses with claims that they were misled or not properly briefed concerning the risks of the positions taken. Since the general public and thus judges and juries find derivatives confusing and risky, even when they are used to reduce risk, such cases or the threat of them may be successful.

A great risk exposure is the extreme scenario which often investors assume has zero probability when in fact they have low but non-zero probability. Investors are frequently unprepared for interest rate, currency or stock price changes so large and so fast that they are considered to be impossible to occur. The move of some bond interest rate spreads from 3 per cent a year earlier to 17 per cent in August/September 1998 led even the savvy investor and very sophisticated Long Term Capital Management researchers and traders down this road. They had done extensive stress testing which failed as the extreme events such as the August 1998 Russian default had both the extreme low probability event plus changing correlations. Scenario dependent correlation matrices rather then simulation around the past correlations is suggested. This is implemented, for example, in the Innovest pension plan model which does not involve levered derivative positions (see Geyer et al, 2002, which I will discuss in the next column). The key for staying out of trouble especially with highly levered positions is to fully consider the possible futures and have enough capital or access to capital to weather bad scenario storms so that any required liquidation can be done orderly.

Figlewski (1994) mentions that the risk in mortgage backed securities are especially difficult to understand. Interest only (IO) securities, which provide only a share of the interest as part of the underlying mortgage pool's payment stream are a good example. When interest rates rise, IO's rise since payments are reduced and the stream of interest payments is larger. But when rates rise sharply, the IO falls in value like other fixed-income instruments because the future interest payments are more heavily discounted. This sign changing interest rate exposure was one of the difficulties in Askin's losses in 1994. Similarly the sign change between stocks and bonds during stock market crashes as in 2000 to 2003 has caused other similar losses. Scenario dependent matrices are especially useful and needed in such situations.

As derivative securities have become more complex, so has their full understanding

6. Forgetting that high returns involve high risk
If investors seek high returns, then they will usually have some large losses. The Kelly criterion strategy and its variants provide a theory to achieve very high long-term returns but large

>

TABLE 1 Yearly Rate of Return on Assets Relative to Cash (%)

Parameter	Stocks	Bonds	Cash
Mean:	108.75	103.75	100
Standard deviation:	12.36	5.97	0
Correlation:	0.32		

TABLE 2 Rates of Return Scenarios

Scenarios	Stocks	Bonds	Cash	Probability
1	95.00	101.50	100	0.25
2	106.50	110.00	100	0.25
3	108.50	96.50	100	0.25
4	125.00	107.00	100	0.25

losses will also occur. These losses are magnified with derivative securities and especially with large derivative positions in relation to the investor's available capital.

Stochastic programming models provide a good way to try to avoid problems 1-6 by carefully modeling the situation at hand and considering the possible economic futures in an organized way. More on that in the next column.

At intermediate times the investor could experience substantial loss, and face bankruptcy

Calculating the optimal Kelly fraction

Most applications of fractional Kelly strategies pick the fractional Kelly strategy in an ad hoc fashion. MacLean, Ziemba and Li (2002) show that growth and security tradeoffs are effective for general return distributions in the sense that growth is monotone decreasing in security. But with general return distributions, this tradeoff is not necessarily efficient in the sense of Markowitz generalized so that growth plays the role of mean and security plays the role of variance. However, if returns are lognormal, then the tradeoff is efficient. MacLean, Ziemba and Li also develop an approach to investing in which the investor sets upper and lower targets and rebalances when those targets are achieved.

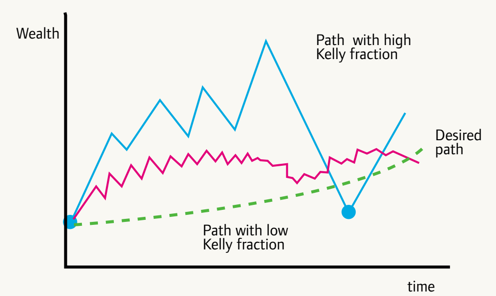

FIGURE 1 Kelly fractions and path achievement

A solution of a version of the problem of how to pick an optimal Kelly function was provided by MacLean, Sangre, Zhao and Ziemba (2003) [MSZZ]. To stay above a wealth path using a Kelly strategy is very difficult since the more attractive the investment opportunity, the larger the bet size and hence the larger is the chance of falling below the path. Figure 1 illustrates this.

MSZZ using a continuous time lognormally distributed asset model calculate that function at various points in time to stay above the path with a high exogenously specified value at risk probability. They provide an algorithm for this. The idea is illustrated using the following application to the fundamental problem of asset allocation over time, namely, the determination of optimal fractions over time in cash, bonds and stocks. The data in Table 1 are yearly asset returns for the S&P500, the Salomon Brothers Bond index and US T-bills for 1980-1990 with data from Data Resources, Inc. Cash returns are set to one in each period and the mean returns for other assets are adjusted for this shift. The standard deviation for cash is small and is set to 0 for convenience.

A simple grid was constructed from the assumed lognormal distribution for stocks and bonds by partitioning $\Re^2$ at the centroid along the principal axes. A sample point was selected from each quadrant to approximate the parameter values. The planning horizon is $T = 3$, with 64 scenarios each with probability 1/64 using the data in Table 2. The problems are solved with the VaR constraint (Table 3) and then for comparison, with the stronger drawdown constraint (Table 4).

VaR Control with $w^* = a$

The model is

$$\max_X \; E\sum_{t=1}^{3} \ln(R(t)^\top X(t))$$

$$\left| \Pr\left[\sum_{t=1}^{3} \ln(R(t)^\top X(t)) \ge 3\ln a\right] \ge 1-\alpha. \right.$$

With initial wealth $W(0) = 1$, the value at risk is a^3. The optimal investment decisions and optimal growth rate for several values of a, the secured average annual growth rate and $1-\alpha$, the security level, are shown in Table 3. The heuristic described in MSZZ was used to determine A, the set of scenarios for the security constraint. Since only a single constraint was active at each stage the solution is optimal.

- The mean return structure for stocks is favorable in this example, as is typical over long horizons. (see e.g. Keim and Ziemba (2000), Dimson et al (2002), Constantinides (2002) and Siegel (2002)), hence the aggressive Kelly strategy is to invest all capital in stock most of the time.
- When security requirements are high some capital is in bonds.
- As the security requirements increase the fraction invested in bonds increases.
- The three-period investment decisions is more conservative as the horizon approaches.

Secured annual drawdown: b

The VaR condition only controls loss at the horizon. At intermediate times the investor could

TABLE 3 Growth with Secured Rate

Secured Growth Rate a	Secured Level $1-\alpha$	Period 1			Period 2			Period 3			Optimal Growth Rate (%)
		S	B	C	S	B	C	S	B	C	
0.95	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	1	0	0	1	0	0	23.7
	0.9	1	0	0	1	0	0	1	0	0	23.7
	0.95	1	0	0	1	0	0	1	0	0	23.7
	0.99	1	0	0	0.492	0.508	0	0.492	0.508	0	19.6
0.97	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	1	0	0	1	0	0	23.7
	0.9	1	0	0	1	0	0	1	0	0	23.7
	0.95	1	0	0	1	0	0	1	0	0	23.7
	0.99	1	0	0	0.333	0.667	0	0.333	0.667	0	18.2
0.99	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	1	0	0	1	0	0	23.7
	0.9	1	0	0	1	0	0	1	0	0	23.7
	0.95	1	0	0	0.867	0.133	0	0.867	0.133	0	19.4
	0.99	0.456	0.544	0	0.27	0.73	0	0.27	0.73	0	12.7
0.995	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	0.996	0.004	0	0.996	0.004	0	23.7
	0.9	1	0	0	0.996	0.004	0	0.996	0.004	0	23.7
	0.95	1	0	0	0.511	0.489	0	0.442	0.558	0	19.4
	0.99	0.27	0.73	0	0.219	0.59	0.191	0.218	0.59	0.192	12.7
0.999	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	0.956	0.044	0	0.956	0.044	0	23.4
	0.9	1	0	0	0.956	0.044	0	0.956	0.044	0	23.4
	0.95	1	0	0	0.381	0.619	0	0.51	0.49	0	19.1
	0.99	0.27	0.73	0	0.008	0.02	0.972	0.008	0.02	0.972	5.27

Table 4 Growth with Secured Maximum Drawdown

Secured Growth Rate a	Secured Level $1-\alpha$	Period 1			Period 2			Period 3			Optimal Growth Rate (%)
		S	B	C	S	B	C	S	B	C	
0.95	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	1	0	0	1	0	0	23.7
	0.9	1	0	0	1	0	0	1	0	0	23.7
	0.95	1	0	0	1	0	0	1	0	0	23.7
	0.99	1	0	0	0.492	0.508	0	0.492	0.508	0	19.6
0.97	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	1	0	0	1	0	0	23.7
	0.9	1	0	0	1	0	0	1	0	0	23.7
	0.95	1	0	0	1	0	0	1	0	0	23.7
	0.99	1	0	0	0.333	0.667	0	0.333	0.667	0	18.2
0.99	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	1	0	0	1	0	0	23.7
	0.9	1	0	0	1	0	0	1	0	0	23.7
	0.95	1	0	0	0.867	0.133	0	0.867	0.133	0	19.4
	0.99	0.456	0.544	0	0.27	0.73	0	0.27	0.73	0	12.7
0.995	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	0.996	0.004	0	0.996	0.004	0	23.7
	0.9	1	0	0	0.996	0.004	0	0.996	0.004	0	23.7
	0.95	1	0	0	0.511	0.489	0	0.442	0.558	0	19.4
	0.99	0.27	0.73	0	0.219	0.59	0.191	0.218	0.59	0.192	12.7
0.999	0	1	0	0	1	0	0	1	0	0	23.7
	0.85	1	0	0	0.956	0.044	0	0.956	0.044	0	23.4
	0.9	1	0	0	0.956	0.044	0	0.956	0.044	0	23.4
	0.95	1	0	0	0.381	0.619	0	0.51	0.49	0	19.1
	0.99	0.27	0.73	0	0.008	0.02	0.972	0.008	0.02	0.972	5.27

experience substantial loss, and face bankruptcy. A more stringent risk control constraint, drawdown, considers the loss in each period using the model

$$\max_X \; E\sum_{t=1}^{3}\ln(R(t)^\top X(t)) \;\Big|\; \Pr\left[\ln(R(t)^\top X(t)) \geq \ln b,\, t=1,2,3\right] \geq 1-\alpha.$$

This constraint follows from the arithmetic random walk $\ln W(t)$,

$$\begin{aligned} &\Pr[W(t+1) \geq bW(t),\, t=0,1,2] \\ &= \Pr[\ln W(t+1) - \ln W(t) \geq \ln b,\, t=0,1,2] \\ &= \Pr[\ln R(t)^\top X(t) \geq \ln b,\, t=1,2,3]. \end{aligned}$$

The optimal investment decisions and growth rate for several values of b, the drawdown and $1-\alpha$, the security level are shown in Table 4.

- The heuristic in MSZZ is used in determining scenarios in the solution.
- The security levels are different since constraints are active at different probability levels in this discretized problem.
- As with the VaR constraint, investment in the bonds and cash increases as the drawdown rate and/or the security level increases.
- The strategy is more conservative as the horizon approaches.
- For similar requirements (compare $a = 0.97$, $1-\alpha = 0.85$ and $b = 0.97$, $1-\alpha = 0.75$), the drawdown condition is more stringent, with the Kelly strategy (all stock) optimal for VaR constraint, but the drawdown constraint requires substantial investment in bonds in the second and third periods.
- In general, consideration of drawdown requires a heavier investment in secure assets and at an earlier time point. It is not a feature of this aggregate example, but both the VaR and drawdown constraints are insensitive to large losses, which occur with small probability.
- Control of that effect would require the lower partial mean violations condition or a model with a convex risk measure that penalizes more and more as larger constraint violations occur.
- The models lead to hair-trigger type behavior, very sensitive to small changes in mean values (as discussed in the column in the March 2003 issue of *Wilmott*; see also Chopra and Ziemba (1993)).

REFERENCES

Chopra, V. K. and W. T. Ziemba (1993). The effect of errors in mean, variance and co-variance estimates on optimal portfolio choice. *Journal of Portfolio Management 19*, 6–11.

Constantinides, G. M. (2002). Rational asset prices. *Journal of Finance 57*, 1567–1591.

Dimson, E., P. Marsh, and M. Staunton (2002). *Triumph of The Optimists: 101 Years of Global Investment Returns.* Princeton University Press, Princeton.

Figlewiski, S. (1989). What does an option pricing model tell us about option prices. *Financial Analysts Journal 45* (5), 12–15.

Geyer, A., W. Herold, K. Kontriner, and W. T. Ziemba (2002). The Innovest Austrian pension fund financial planning model InnoALM. Working paper, UBC.

Keim, D. and W. T. Ziemba (Eds.) (2000). *Security Market Imperfections in Worldwide Equity Markets.* Cambridge University Press.

MacLean, L., R. Sanegre, Y. Zhao, and W. T. Ziemba (2003). Capital growth with security. *Journal of Economic Dynamics and Control*, in press.

MacLean, L., W. T. Ziemba, and Y. Li (2002). Time to wealth goals in capital accumulation and the optimal trade-off of growth versus security. Working paper, School of Business Administration, Dalhousie University.

Siegel, J. J. (2002). *Stocks For The Long Run*. Wiley.