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Seeing is not believing: Fund of Fund and Hedge Fund Risk Assessment and Transparency, Survival and Leverage

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You can't manage what you can't measure

This paper deals with some of the issues and difficulties involved in evaluating hedge fund risk and reward. These issues are particularly relevant when evaluating the value add of using a fund of funds as an intermediary. I focus on the logical necessity of flaws in observational return type data and the analytic methods associated with these data. And although positional level data has its own failings, some of which are reviewed here; the unavoidable conclusion is that without position level data, risk assessment is highly questionable. Among the issues discussed are survivorship bias and leverage. The last sections cover the basics of leverage.

Ultimately risk assessment must include manager analysis and evaluation by experienced individuals. A careful and skeptical analysis of returns, positions, etc., can lead to penetrating questions that can aid the manager analysis process. But the data must be taken with a grain of salt and must be intelligently interpreted. Much of this paper delves into the nature of the salt.

Although I attempt to expose some of the weaknesses in data and the difficulties in evaluating risk from an investor's viewpoint, and I use survivor bias, VaR, Sharp Ratios, Leverage, etc., to illustrate my point – this paper is not about these particular measures per se. It is about risk. It is about the conceptual difficulties in assessing that risk.

Though some flaws in return data might be mitigated by improved systems and improved analytics - these tools can only provide a necessary framework for risk management; they cannot produce a sufficient framework. Only a robust positions level processing system/analytics can do justice to quantitative risk assessment. But, beyond the data that will always remain less than perfect, only capable risk personnel can come close to providing the ultimate risk assessment value in a hedge fund or a fund of funds. Real risk is something that hasn't happened before[1]. And dealing with it requires intelligence and flexibility. However, this observation doesn't mean that tools based on history have no value. Indeed, experience is ultimately the only defense against uncertainty.

The President's report on Hedge funds stated that in mid 1998, 200 billion to 300 billion dollars capital was under hedge fund management and there were between 2,500 to 3,500 active hedge funds[2]. A recent estimate of the size of the hedge fund industry was recently put at 600 billion dollars and over 5,000 currently active hedge funds and fund of funds[3].

Hedge funds are essentially unregulated investment vehicles and provide a great degree of latitude in investment style, positioning and strategic trading techniques with unconstrained leverage, short sales, etc. - more than perhaps any other financial vehicle. Fund of funds are financial organizations that manage portfolios of hedge funds.

The segment of the capital markets covered by hedge funds is still small compared to the entire market so the market has room to grow. For comparison, the

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[1] Risk Management in Complex Organizations – Richard Bookstaber

[2] Hedge Funds, Leverage and the Lessons of Long Term Capital Management – Report of the President's Working Group on Financial Markets – April 1999

[3] Source: Chicago based Hedge Fund Research report released 3rd quarter of 2002

current size of the American mutual fund industry is about 7 trillion dollars[4] (in terms of assets managed) with Vanguard alone managing about 654 billion in 2001. According to a Pensions and Investments report, in 2000 the pension industry had upwards of 5.4 trillion in assets under management and had upwards of 4.7 trillion in assets under management in 2001[5].

One has to take the figures for money managed by hedge funds with some healthy skepticism. The dollar amounts quoted are for *assets under management* – not for total capital under control or subject to some form of risk. Dollar for dollar, for hedge funds, the ratio of capital under control or *under the influence* to value of assets under management is much higher than the corresponding ratio for mutual funds or pension funds. Yet, this ratio (which might be referred to as leverage or at least related to leverage in some way) is, at best, nebulous in terms of its connection to something meaningful and easily interpreted[6].

As water seeks its own level so does investment capital. Money is starting to move from the more traditional investment vehicles into hedge funds, often using fund of funds as an intermediary. It has so far been a trickle from Pension funds. But a trickle from pension funds means several billions of dollars. There is talk in the mutual fund industry of creating mutual funds of hedge funds. This could open a floodgate of capital to the hedge fund industry. As money flows into hedge funds, so does risk.

The fundamental underlying idea responsible for driving the capital flows in the direction of fund of funds and hedge funds is that hedge fund managers are thought to be the highest skilled money managers in the business. So a portfolio of hedge funds offers the possibility of higher returns, and skilled second tier managers of fund of fund portfolios directed by skilled professionals offer the possibility of optimal diversification over a variety of strategies.

Each manager has a focus and a specialty and brings some core advantage to the table. There are a plethora of strategies and managers within strategies that should diversify each other in a well-structured portfolio of funds. Using a fund of funds as a vehicle for choosing the hedge fund portfolio seems like a reasonable tactic. If a fund of funds is well managed, it is reasonable to suppose that the resulting portfolio of hedge funds will be designed in a rational manner. The usual fee structure for hedge funds is usually 1% to 2% or more of assets under management for a base management fee plus an incentive fee, and the fee for a fund of funds is usually about 1% of assets under management plus an incentive fee, fund of fund fees are on top of hedge fund fees.

Given that the hedge fund industry is not completely transparent, what information is available for decision making to even the shrewdest investor or the best managed fund of funds? Furthermore, how can one judge if a fund of funds is well managed and is actually adding value? The answers to these questions are in the details and most investors are probably not equipped to analyze the details in depth. How many

[4] The Mutual Fund Industry: An Overview and Analysis. Jim Saxton (R-NJ, Chairman, Joint Economic Committee United States Congress, February 2002.
[5] Pensions and Investments, P&I 1000 Statistics at a glance, January 21, 2002. http://www.pionline.com/pension/

[6] The concept of leverage and its interpretations is discussed later in this document

investors understand the subtleties of convertible bond arbitrage, statistical arbitrage, emerging markets, distressed securities trading or derivative pricing?

Available quantitative information usually comes in two main flavors: returns and positions. Sometimes summary information like greeks or sensitivities to various market risks are available but this information is usually limited as to its accuracy and the extent to which it can be interpreted. Statistical risk and summary reports, such as VaR, Sharpe Ratios, volatilities, counter-party exposures, liquidity information, etc., can then be generated based on the return and position data. But if the available return and position information is flawed; it is possible for even intelligent, experienced people to misinterpret what they see. Information may not be as it appears to be and one must go deeper to develop an understanding. I'll shed light on some of the conceptual issues that arise in observational data used to evaluate a hedge fund's performance and risk.

For seasoned funds, a track record of returns is usually available. New funds, of course, have no track record and no return history. Another source of information is hedge fund positions. Usually when the term 'transparency' is used, it is used with regard to knowledge of positions or at least some position level information.

This paper will discuss issues associated with returns and positions and various risk measures. We'll review where the failings and limitations are. Not because my belief is that there is a possibility of perfect risk measures, but because I believe investors can be misled by not understanding the limitations of risk assessment. And because I believe that unless serious risk management practices are established, risks can cascade. One can imagine an economic dooms day scenario in which funds explode like so many disparate firecrackers followed by an ensuing chain reaction. Without appropriate risk management in place on a fund by fund basis, this scenario could become a reality.

Before entering the realm of risk measurement statistical issues and detail, I want to put forth a view on the risk management industry as to how it relates to and functions within the financial community, with hedge funds and fund of funds in particular focus.

Several examples of large hedge fund blowups are available from the past several years. As increased capital flows to hedge funds; returns may be harder to generate, additional risks may be taken in response to diminished returns. In the past, as a result of large hedge fund blowups, some analysts have looked at the data and concluded that risk models were responsible because they broke down in the real world, which is different from the theoretical world in which they were constructed. On a well known financial television show during the time of the derivatives crisis in the 90's, it was once said that financial mathematicians sit in dark rooms, eating raw meat and creating strange equations that no one understands and this is what is at the bottom of the increasing risk to our financial systems.

Nothing could be further from the truth. Most hedge fund managers are not stupid[7]. They are not ignorant of the limitations of mathematics as applied to financial risk. Some of the biggest blowups had at the helm some of the best and brightest. They knew what their risks were and they took chances. They took highly leveraged, unhedged bets and they lost. No amount of statistical analysis or systems or mathematics will

[7] Although stupidity and ignorance are great legal defenses when there are financial blowups. It is a wonder of our times that ignorance of the law is no excuse when going through a red light or speeding in traffic, but ignorance of derivatives, their inner-workings and pricing, is a great defense for those who make unhedged bets and blow up.

prevent individuals from making complex bets if they choose to make those bets and nothing stands in their way; including, but not limited to, their own in-house risk management area. Any risk system can be gamed if a knowledgeable enough individual chooses to game it. There is risk in the future; risk that large, un-hedged bets will once again go awry. The only thing that may help prevent or minimize these future events is intelligent, empowered and unfettered risk people - internal to funds and fund of funds and viewed as an integral part of the business - who have the authority to take action and have the appropriate tools at their disposal.

In past blowups, so-called sophisticated risk tools may have given false impressions to the uninitiated, and a resulting false sense of security. But the knowledgeable insider understood the risks being taken. Yet personal motive and personal agenda can override decision making in any enterprise – no less the hedge fund business.

All risk models and tools are flawed. Yet without the models and tools, there is increased risk. With them there is the danger of misinterpretation or misapplication or too much trust resulting in laxity. A defective tool may be better than no tool at all – but that is all. So the question arises; not only how do we protect investors from risks they do not understand, but even more importantly; how do we protect society from risks it does not know it is taking?

Since hedge funds are proprietary trading vehicles, they are secretive. They are protective of strategic information. Information is ultimately their edge. In some cases, that information can be gleaned from knowing their positions. Information is also implicit in their strategies. So for many hedge funds, keeping information about positions and detailed strategies secret is in their interest; whether that information actually is an edge or just a perceived edge. A prudent investor might want to know how their money will be invested; what the positions are and is there a way of obtaining a valuation check on them. They might want to know what the inherent risk is. They might want to know how they can diversify their investment over several hedge funds. Thus the concepts of hedge fund transparency, diversification and risk assessment arise accompanied by the implicit, opposing forces of secrecy and strategic edge.

There is a movement in the industry to embrace risk management. This can take several forms. It can mean the building of in-house systems. It can mean the buying of risk information from providers, produced and packaged in a variety of ways. Building or buying is one of the issues on the table. A well set up risk management function should encompass both build and buy systems solutions. Building alone is too expensive; buying alone can be too restrictive. Building in house leverages the company because local talent is created. Buying leverages the company away from projects it does not want to get bogged down in, does not want to divert capital or human resources to – and leverages the company by allowing it to focus resources on its core talents and advantages.

Though building or buying and the issues embedded in each of these decisions leads to complexity, they are not the only issues on the table. How to set up internal risk management structures is also an issue and it isn't a simple one with simplistic solutions. What should the reporting structure be? A separate but equal structure may provide independence but may also provide a communication breakdown and resource contention. Will risk management be perceived as a cost center without any real internal value or will it be perceived as a necessary part of the profit center business? Will risk management be set up as a facade to satisfy regulator and investor perceptions, or will the risk management area be set up as a fully integrated business function as an equal partner to other business functions? Management discussions are needed on an individual firm level to frame risk management within the specific environment of that particular firm. Real risk management is not simply concerned with generating statistics; it also consists in taking part in fundamental decision making.

Management cannot overlook the need for qualitative and subjective decision-making – in the case of a fund of funds – judging managers on an individual level based on experience rather than statistical information only. Experienced risk management personnel should be involved in this process. This is one of the areas in which a well-run fund of funds can add real value. Judgment must rest on a combination of statistical analysis and experience and real access to individual managers and their operations.

The function of Risk Management should not be treated like a facade that is only there to give an impression that something is being done. It should not be used as a veneer whose only purpose is to draw investor capital. A Risk Management area must be viewed as a full and equal partnership in the profit side of the business. Senior risk management should have full authority to take action. For a fund of funds, this means being involved in the interviewing process when selecting managers. It means kicking the tires of existing managers. Senior Risk Managers must consist of experienced, street savvy individuals with a strong knowledge of the markets and hands on business experience. There are a great many PhDs on the street but having a PhD is not enough or even necessary. When I ran a quant group at Bankers Trust, and in my current position at Measurisk, I generally have interviewed up to 30 PhD entry-level candidates before I hire one. Paperwork and pedigree is only part of the wallpaper. Knowing how to put together a strong risk team is not a slam-dunk. But not doing it correctly adds a special kind of risk – the kind that comes from thinking you have a gun at the ready when you do not. You do not want to be in the position of reaching for your weapon at *High Noon*, only to find your holster is empty.

I've tried to keep the mathematics in this paper to a minimum in order to provide accessibility to a large audience since; I believe these issues are relevant not only to the industry but to society as a whole.

Returns Series data

Quantities like average returns, betas and correlations, volatilities and VaR, and Sharpe Ratios can be extracted easily from return series to describe how a particular fund behaves relative to other funds or market factors. Sharpe Ratios are particularly handy when thinking risk reward and are probably the most popular measure of risk reward in use[8]. All these measures are useful if one understands their limitations and how they might be applied or misapplied. But even these simple and straightforward measures can have somewhat less than crystal clear interpretations. This section describes some of the issues involved when evaluating a hedge fund in terms of these common descriptive statistics.

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[8] Hedge Fund Survey Overview, Capital Market Risk Advisors, May 15, 2000, p.11

A word on returns and descriptive statistics

There are some subtleties even before we start. Most analysts are concerned with monthly return data. Published volatilities, betas, Sharpe Ratios, etc., are based on monthly returns. Consider the following monthly return history of fund GOODUNTILITGETSBAD Partners:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Return%	50	50	50	50	50	50	50	50	50	50	50	-100

Table 1: Fund GOODUNTILITGETSBAD Partners

Fund GOODUNTILITGETSBAD Partners had 50% monthly returns for the first 11 months of its existence. Very impressive. Then it lost 100%. Since it lost 100% in the 12^{th} month, the investors lost their entire initial investment. Another way of saying this is the overall return was –100%. Yet the arithmetic average monthly return was $\frac{11*50\%-100\%}{7}=37.5\%$. Not bad. Fund GOODUNTILITGETSBAD Partners returned an average of 37.5% per month for a year. On the other hand, its investors lost everything.

The annualized volatility is typically calculated as the standard deviation of the monthly return numbers times the square root of 12 to annualize (12 months per year). This leads to a vol of 143.6%. Annualizing monthly returns leads to a 450% return = 12 * 37.5%. The Sharpe Ratio, ignoring the minor effect of the risk free rate, is 3.1. A Sharpe Ratio of 3.1 is considered very good. So by the most commonly used measures for determining performance from returns, fund GOODUNTILITGETSBAD Partners did unusually well in the first year of its existence. Of course, it went belly up.

Monthly return data can be misleading. Yet that is what we generally have, and it is what most investors and analysts look at. One reason analysts look at monthly returns is because it gives them as many data points to use for statistical parameter estimation and for statistical testing as is generally available from fund managers. Also it is homogenous data. That is, if each observation is on a non-overlapping monthly basis, the results are cleaner. If each observation was from the initial investment to the current month the observations would be overlapping and straightforward volatility calculations (commonly over non-overlapping intervals) would no longer be available. Also the point in time at which you define the initial investment to take place would be arbitrary and can lead to arbitrary conclusions. So, generally, we are stuck with monthly return data.

There is one risk measure that might give a somewhat different picture: Value at Risk, more commonly referred to as VaR, which rhymes with jar, bar and car. VaR can be defined as the amount you can lose with a probability of 5% (any percentage can be used). 95% of the time, you won't lose this much. Of course, 5% of the time, you'll lose more. And these statements are made under the assumptions that *times* are pretty normal and stable and reflected in the data. If something happens that is not reflected in the past data, all bets are off. This fact is sometimes given as a reason for not using VaR. The losses estimated by VaR are loses that occur given that everything behaves normally. But when large losses occur, things are anything but normal. But the fact that you cannot predict the future would be an equally valid criticism of any risk measure based on history, not just VaR. In fact it would be a criticism of most of human thought. It is a practical limitation for statistical risk measures but perhaps a necessary one. Another criticism of VaR is that it does not pick up all risks. Again, that is true about any risk measure. There are more solid reasons for criticism of VaR.

VaR might give a somewhat different picture of the GOODUNTILITGETSBAD Partners return history because VaR asks the question: How much can you reasonably expect to lose if the past is indicative of the future? When one calculates average returns or volatilities of returns, the number of observations that go into the calculation is equal to the number of returns available. But in the case of VaR, when we look at one return history consisting of many returns, we only have one path; one observation as far as VaR is concerned. You started with a certain amount of equity capital and in the end you were left with a certain amount. This is the view because of the way the question was asked: How much can I lose? Intermediate returns don't matter. And in our one observation, all the money was lost.

But the definition of VaR tends to be played with a bit, loosened up, and one could restate it as: How large a return loss might I reasonably experience (at the 5% level)? We still only have one observation; beginning to end. But we might think that we can pick up some statistical information from the return history that might help answer the question. We pretend the 12 returns can be aggregated into one random sample as though they have been applied to the same starting amount[9]. In this case, we calculate directly from the monthly return data that the probability of returning 50% is 11/12 and our only loss occurred with a probability of 1/12 = 8.33%, which is greater than 5% probability but there is no greater loss that can occur. So, using this technique, we calculate the VaR for the GOODUNTILITGETSBAD Partners fund and we find it is –100% (VaR = -100%). In this instance, this particular VaR calculation seems to provide more accurate information than average returns, volatility or Sharpe Ratios.

But notice that although the 5% VaR is –100%, that loss does not occur with 5% probability, it occurs with 8.33% probability. This is one of the weaknesses of VaR or any statistic that attempts to make a probability statement: If payoffs are setup in such a way that the loss function is a step function, then the probabilities break down.

For example, suppose you are long an at-the-money call option and it has about a 50% chance of being in the money and a 50% chance of being out of the money at expiration. Then, given a horizon equal to the expiration, the amount you can lose with 50% probability is the premium. VaR asks a question that sounds something like: 'How much can I lose in a worse case scenario defined as no more likely than one chance out of twenty or 5% chance of occurring?' Intuitively the user of VaR thinks a loss that has less than a 5% chance of occurring has got to be more than a loss that has a 50% chance of occurring. But the most that can be lost in our example is the option premium. And that has a 50% chance of happening. The loss function is a step function; VaR will be calculated as the option premium but the probabilities are wrong. The answer is misleading.

The fundamental issue is that VaR attempts to do what everyone would like it to do – it attempts to measure the loss in the extreme left tail. Because of this, it is forced to associate a probability with its calculation. This is its Achilles heel. It is this probability that will not be valid when the market collapses. It is this probability that breaks down for

[9] This is sometimes how *historical VaR* is calculated.

certain kinds of derivative payouts. The problems worsen as you move further into the left tail. So 1% VaR is less robust than 5% VaR, etc. *Any* extreme value calculation made based on a statement of probability will have the same failing – not just VaR. Even if the probability statement is worked around, just the fact that you are attempting to extract a statistic describing a rare event will be misleading because the nature of a rare event means data describing it will be sparse.

One way around this weakness of probability-based measures is to use a risk measure like downside volatility that requires no probability estimate. But there are other applications in which a probability measure is necessary, like when it is used for determining capital adequacy.

All criticism aside, VaR is generally a useful risk measure in the right hands. If it is interpreted in an intelligent way with adequate drilldown and tracking capabilities, then risk personnel can track portfolio changes on any level due to changes in position or changes in market conditions and attribute increasing or decreasing risk to the proper source.

There are more complexities when dealing with return data than I have covered here[10]. But given the backdrop of this basic discussion, let's look at more involved issues and implications.

Survivorship Bias, Sharpe ratios, and incentive for leverage

One reason hedge fund returns data is biased is because funds that fail are dropped from the database so observations based on the remaining returns and Sharpe ratios are biased upwards[11]. This is not meant to be a criticism of data collection techniques. It is just an observation based on necessity and reality; hedge funds that fail necessarily fall out of data collection because they no longer exist. One might ask the question: are the funds that remain alive, winners or are they just lucky?[12] In this sense survivorship bias is not just the bias resulting from ignoring returns of failing funds in statistical calculations, but it is also the bias that results from simply not having failed.

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[10] One issue is: how do you calculate average returns and how do you annualize them? For instance: the growth of money over time is $\prod_{i=1}^{n}(1+R_i)$ where each R_i is a monthly return over a series of n monthly intervals. Then the average monthly return is $\overline{R}=\left(\prod_{i=1}^{n}(1+R_i)\right)^{\frac{1}{n}}-1$ and the equivalent annualized return is $R_A=\left(1+\overline{R}\right)^{12}-1$. Using this method would lead to an overall average annualized return of –100% in the example. But most people just use straight arithmetic averaging and that is the approach I use in this paper.

[11] Some funds may drop out of the database because they fail. But a poorly performing fund can be closed in order to be started up again under a different name and a clean return history. In this case, a blowup is not required. Funds may also voluntarily drop out of return reporting for a variety of reasons, thus convoluting the results and conclusions.

[12] One could make the analogous observation with regard to other businesses or enterprises but the difference is that hedge funds are completely and fundamentally characterized by returns – that is the business – that is the commodity they produce.

Highly leveraged funds are more likely to fail. But if a highly leveraged fund gets lucky and does not fail, it has a higher likelihood of outperforming its less leveraged cousins – a bigger bet is on the table. If the table doesn't cave in, a bigger bet is a better bet.

These observations are generally referred to as survivorship bias. The simple act of being there is an upward bias on returns.

There are many confounding effects: What was happening in the markets when the data was collected? Was it a time of large mergers? Was it a time of extreme stock market performance? (During the dot com boom, hedge funds failed based on decent returns even though they made money but didn't perform as well as the, then, inflated stock market. So the performance required to define failure can depend on relative local market conditions.). What kind of strategy was the hedge fund using? Was there drift in the strategy over time (that is, was there one well defined stable strategy over time or did the strategy change erratically or smoothly over time?)? How leveraged were the funds that failed and how leveraged were the funds that survived?

In order to circumvent these confounding factors and to clarify the relation between survivorship, leverage, VaR and Sharpe ratios in a purified environment, I created the following *thought* experiment. I defined a strategy I call 'coin-flipping'. A coin-flipping fund is one in which the manager flips a coin and if the coin is heads, they buy the S&P500. If the coin comes up as tails, they sell the S&P500. The amount they buy or sell depends upon desired leverage. To keep things simple, they buy or sell at the end of month at the closing price. There are no transaction or funding costs. There are no liquidity issues. All this is to keep things simple and to not convolute results.

The manager flips a coin once a month and reports results, which are based on month end mark to market. There are many of these funds – in our computer simulated world - with a range of returns because each manager flips his or her own coin independently from all other managers and therefore buys and sells in differing sequence. At random, some of these funds will do well, and some will not. I use a monte carlo method to generate many simulated fund's return histories and calculate the appropriate statistical quantities on the survivors to examine the bias. Volatilities are annualized but VaR results are not – they are just relative to the period in question.

On average, returns and Sharpe ratios for the coin flipping funds should be zero since there is no ability involved, no information advantage, and no bias. I define failure as losing 30% or more of original equity invested. If the 30% loss hurdle is reached or exceeded, the fund is closed and any remaining capital returned to the investor. The investor cannot lose more than original equity invested (limited liability). Hedge funds can be levered enough so that an extreme loss event may occur in which more than total equity invested is lost. Yet investors are protected at zero. That is; the investor implicitly owns a put option on the fund struck at zero[13]. And this is factored into the analysis.

Monte carlo simulations were run based on the coin-flipping strategy. The results are summarized in Table 2 and Table 3 below. Both tables are based on S&P500 monthly closes. Table 2 presents results for the period Jan 2000 through Sept 2002 and Table 3 presents results for the period Oct 2001 through Sept 2002. Two different time period

[13] Managers implicitly own a call option based on their compensation and fee structure. See Careers and Survival: competition and risk in the hedge fund and CTA industry, Brown Goetzmann and Park, Oct 29, 2000

lengths were chosen because time period length strongly impacts results. All other things held constant, the longer the time period, the more likely it will be that the funds will fail. Eventually, over a long enough time period, they will all fail with certainty. Presumably this is not so different from the situation in reality. If there is a finite probability that a given fund will fail, then the probability of ruin is high that eventually the fund will fail over a long enough time period.

Leverage	% Survivors	Average time in years until failure occurs	Annualized Volatility of Survivors	VaR of Survivors	Minimum Sharpe Ratio of Survivors	Average Sharpe Ratio of Survivors
1	76%	1.77	18.3%	-24.3%	-0.62	0.24
2	39%	1.16	36.5%	-22.3%	-0.17	0.52
3	23%	0.78	54.3%	-20.2%	0.04	0.68
4	16%	0.65	72%	-18.5%	0.19	0.80
5	11%	0.65	89.4%	-17.0%	0.33	0.90
6	8%	0.64	106.5%	-15.5%	0.46	1.01
7	6%	0.62	127.9%	-13.0%	0.60	1.12
8	4%	0.60	139.1%	-10.4%	0.77	1.25
9	2%	0.58	154.0%	56.6%	0.88	1.42
10	1%	0.55	169.3%	99.7%	0.98	1.52

Table 2: SURVIVOR BIAS FOR COIN-FLIPPPING S&P500 FUNDS AS A FUNCTION OF LEVERAGE Jan 2000 through Sept 2002

Leverage	% Survivors	Average time in years until failure occurs	Annualized Volatility of Survivors	VaR of Survivors	Minimum Sharpe Ratio of Survivors	Average Sharpe Ratio of Survivors
1	96%	0.88	18.8%	-25.0%	-2.02	0.09
2	67%	0.72	37.8%	-25.6%	-0.74	0.54
3	45%	0.60	56.1%	-25.1%	-0.32	0.84
4	29%	0.29	73.6%	-23.2%	-.04	1.06
5	24%	0.31	91.0%	-22.5%	0.17	1.22
6	19%	0.32	107.6%	-21.7%	0.39	1.38
7	15%	0.34	123.3%	-15.0%	0.59	1.57
8	12%	0.35	138.1%	-12.4%	0.90	1.76
9	9%	0.35	152.0%	68.9%	1.02	1.93
10	8%	0.34	166.4%	81.9%	1.18	2.05

Table 3: SURVIVOR BIAS FOR COIN-FLIPPPING S&P500 FUNDS AS A FUNCTION OF LEVERAGE Oct 2001 through Sept 2002

Survivorship bias and its relation to leverage and Sharpe ratios are more complicated in the real world. But in the idealized world of coin-flipping funds, the relation is obvious. Without survivorship bias, the Sharpe ratio would be zero (based on a risk free rate of zero) because the average return should distribute around zero[14].

But as we can see from the above analysis, with survivorship bias, the Sharpe ratio increases with leverage - higher leverage implies a fund is less likely to survive, but if it does survive, it will have a higher Sharpe ratio. Its survival in our case means it has not had any large losses (>30% losses relative to initial equity). I have simulated the removal of any fund that fails from the database, keeping only those funds that have not lost 30% or more. Since I've imposed no limit on the upside, the distributions of the remaining funds are skewed to the upside. Thus without any skill whatsoever, funds that continue to exist demonstrate this characteristic of return skewing toward the upside, resulting in higher Sharpe Ratios.

With a leverage of 1, from Table 2, we see that 76% of all funds survived from Jan 2001 through September 2002, that is, 24% failed in the 1.75-year period. With a leverage of 2, 61% fail. And from Table 3, only 4% of the funds failed in the shorter 1-year period (Oct 2001 through September 2002). With a leverage of 2, 33% failed in the same period.

Estimates of the rate of failure of hedge funds fall in a fairly large range and are somewhere between 4% and 25% per year, CTA's are said to fall nearer to the 20% attrition rate [15] [16]. It's not in the above tables, but the maximum Sharpe Ratios were 3.25 for the Jan 2000 – Sept 2002 period and 3.85 for the Oct 2001 – Sept 2002 period. Sharpe Ratios over 3 are unusual and would call attention to a fund. These occurred randomly and there is no predictive difference between the coin-flipping funds with high Sharpe Ratios or those with low Sharpe Ratios.

Performance, as measured by Sharpe Ratios, is linked directly to leverage. Risk as measured by VaR is linked directly to leverage. Both statements are true because of skewing of the data. The funds that live only live because they haven't happened to lose 30% or more. This skews the data and defines the relation between Sharp Ratios, VaR and leverage. See Figure 1 and Figure 2 below.

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[14] I am using a zero risk free or reinvestment rate for ease of interpretation. In the special case of a zero risk free rate, the Sharpe ratio reduces to the information ratio. Leverage should increase both returns and standard deviation of returns in direct proportion. So an information ratio, which is the ratio of average return to standard deviation of returns (volatility), should not be affected by leverage. Yet in the tables, the ratio is definitely a function of leverage because of skewing.

[15] Welcome to the Dark Side, Hedge Fund Attrition and Survivorship bias over the period 1994-2001, Amin and Kat, December 2001

[16] The Young Ones, Cross Border Capital, April 2001

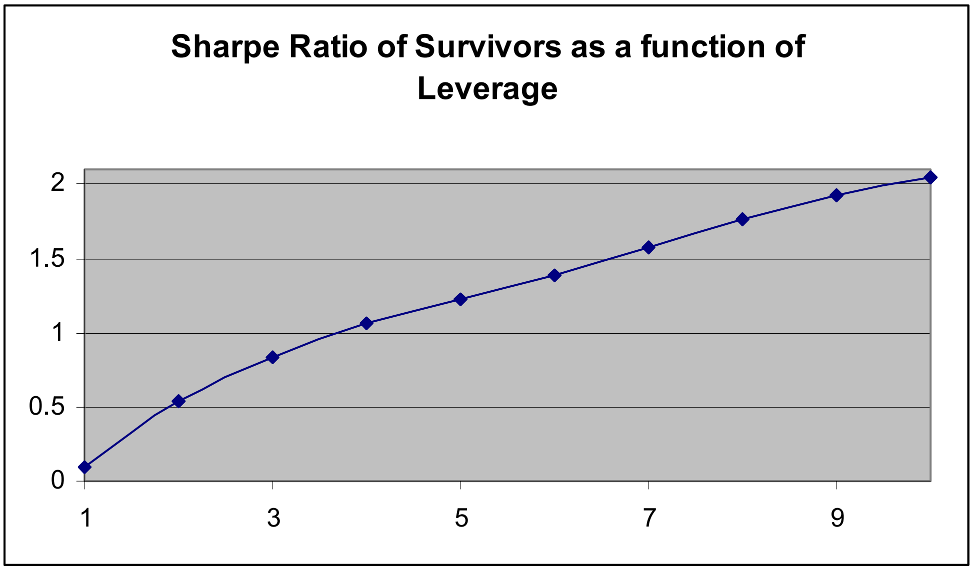

Figure 1: Survivor Bias - S&P500 Coin-Flipping Funds Sharpe Ratio as a function of Leverage Oct 2001 – Sept 2002

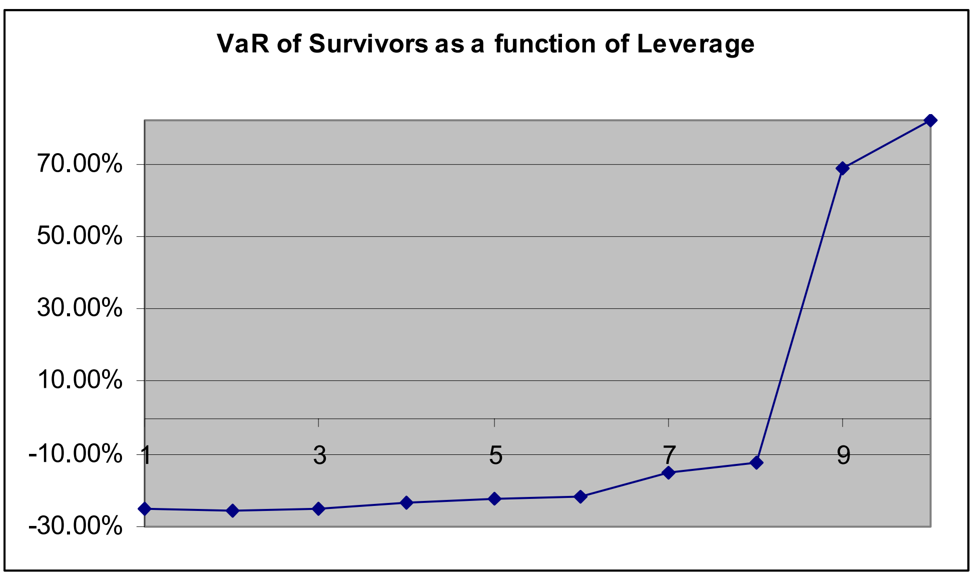

Figure 2: Survivor Bias - S&P500 Coin-Flipping Funds VaR as a function of Leverage Oct 2001 – Sept 2002

The VaR results may seem counter-intuitive. But since losing funds have been eliminated from the database, returns are skewed to the upside. As leverage increases, the skewing becomes more pronounced. VaR measures the 5% tail loss. Since all funds that lost more than 30% are eliminated, VaR cannot show higher losses than 30%. In fact, it has to be somewhat less than that because there will be 5% of funds that lose more than VaR and not in excess of 30%.

As leverage increases, those funds that lose, lose a lot (magnified by leverage). So coin flipping funds that survive are winners. Based on history, the likelihood of them losing anything diminishes with increasing leverage. Thus VaR eventually becomes positive. VaR seems to indicate that for the highly leveraged funds, it is impossible to lose. Of course, if the losers were kept in the database, results would tell another story. But VaR conditioned on winners - even random winners - says the more leverage, the better.

Volatilities tell a somewhat different picture, growing with leverage but still underestimating risk somewhat. Unconditioned volatility of returns increases linearly with leverage. This effect is somewhat dampened by the skewing of the distribution of returns toward the positive.

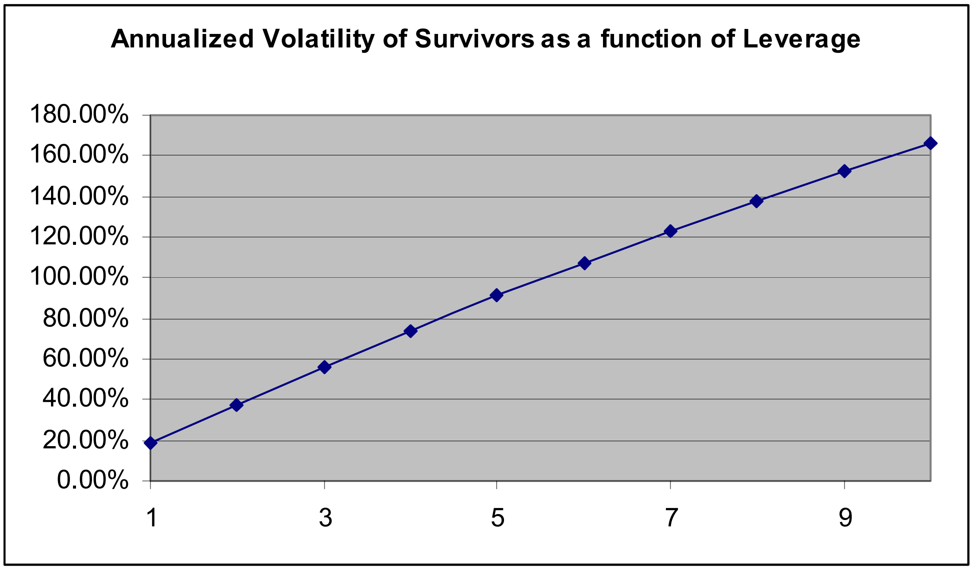

Figure 3: Survivor Bias - S&P500 Coin-Flipping Funds Volatility as a function of Leverage Oct 2001 – Sept 2002

The bottom line of this study is that when you look at survivors, you see higher Sharpe ratios associated with higher leverage. Funds might look less risky than they are simply because they are still alive. And this observation is not only true for this made up universe of funds in which only randomness is at work. It is true in the real world of funds too - even when randomness is joined by skill. And where leverage can reach exceedingly high levels[17].

In summary, there are issues of accuracy, even of reflecting reality, with return data. There may be other bias besides survivorship. Manager's fee structures are related to returns. It is in their monetary interests to show higher returns. There is a certain degree of flexibility in how positions are marked to market[18]. There might be secrecy around positions. So a high level of trust is required.

Most managers are honest and the reported numbers can be trusted, at least to some extent. But the only way to know for certain what returns really are is to withdraw

[17] Risk Management lessons from Long-Term Capital Management, Philippe Jorion, January 2000
[18] See the next section on positions

capital. On the other hand, return data that does not reflect reality over the long term most likely will eventually result in failure and perhaps prosecution. A long stable history of consistent returns may indicate real value and in the best case, second order characteristics of that data may be used to extract information on liquidity[19], etc. But a better scenario is for a risk manager or investor to have the capability of going beyond return histories.

Positions

The statement of 'a need for hedge fund transparency' implicitly refers to the availability of some form of information on positions. The most complete form of position information is contained in the positions themselves. A lesser form of information might be the top ten positions, or aggregate portfolio sensitivities generated by managers, etc.

Hedge fund managers may not want to provide full position disclosure because of the proprietary nature of the information the positions contain. An educated eye looking at positions may extract a proprietary strategy. Knowledge of large positions could cause front running, etc. A liquidity crunch can be made worse if others outside of the fund have position level knowledge.

New managers who don't have track records usually don't mind providing positions if their investors request transparency. Even many seasoned managers, in spite of the concerns, will disclose positions. Managers sometimes have fewer objections to providing positions to third party risk vendors that they would if asked to provide the same information to investors or to a fund of funds. But even if position level information is available, without sophisticated processing capabilities, little real value can be extracted.

Before going into some of the details and difficulties associated with making use of position level data, let's say this: It is better to have positions than not. If sophisticated tools are available in the right hands, a great deal of information about market, credit and liquidity risks can potentially be extracted. One of the most important and fundamental pieces of information gleaned from positions is pricing. Being able to obtain a check on pricing can prevent or detect fraud. But pricing is not a trivial pursuit.

Pricing

Exchange traded securities are the easiest to price. They are marked to market on an exchange and that is the final word. But is it? A fund with a large position in a single exchange traded security cannot reasonably expect to unload that position at the then current market price. Depending on how much of the position is traded at a given time will determine what the haircut should be. Thus, marking to market for large positions can be a bias favorable to the fund. Some funds do not adjust for this factor.

Pricing illiquid securities can be even more difficult. A manager may call several dealers to obtain a price. They may obtain four or five prices and then throw away the outliers and take the remaining average[20]. There is definitely noise in this pricing.

[19] See the well written paper: Risk Management for hedge Funds, Andrew Lo, June 7, 2001
[20] CMRA NAV/Fair Value Practices Survey Overview, http://www.cmra.com/html/nav.html

When it comes to complex derivatives, many managers themselves do not possess the models required for pricing. They may depend on the sell side dealers who are their counterparties in the trade for a mark.

Derivatives are priced through the use of theoretical models in which underlying market observable and not so observables are inputs. The source of the pricing is sell-side dealers. Hedge funds will either call the dealers for marks or they will do the pricing themselves (or their fund administrator or prime broker). Different dealers may have different marks. A complex derivative will have a wide bid ask spread and the fund will tend to want to deal with the original dealer to unwind because they don't want to stand between dealers and risk disparate pricing on both ends.

The pricing of derivatives is not hocus-pocus but correct pricing can be subtle. Even the sell-side dealers with their heavy quant resources have differing levels of expertise though most will agree closely on pricing as a particular derivative market matures. But sometimes there are theoretical issues, which are difficult to deal with, and pricing can change because of improvements in modeling.

I will use a story to shed light on this issue. I ran the quant team at Bankers Trust from the middle 80's to the middle 90's – a time when there was great innovation in the derivatives business. BT's business model was based on creating pricing that other houses would converge to as that particular derivative market matured. BT would get there first and go on to something else when the spreads tightened. This particular story concerns the Indexed Amortizing Swap (IAS) market (same as the Indexed Principal Swap market - IPS).

An indexed amortizer is a swap whose principal amortizes down as libor decreases – thus simulating the prepayment effect in a mortgage. At the time, there was a demand from the buy-side to receive fixed on these swaps. We recognized early on that we needed a multifactor interest rate model to do the pricing even though there were several one-factor approaches available.

In a one-factor model, long rates and short rates decrease together so pay-down can only occur when long rates (in particular) are low (in the simulated world of the model). This is exactly when a receiver of fixed does not want the swap to pay off because a fixed receiver will be receiving higher than market rates exactly when the swap amortizes away. Long rates and short rates tend to also increase together in a one-factor model. When long rates are high, a fixed receiver will be receiving a low coupon relative to current (model simulated) market rates and would like the swap to amortize away but short rates are high and the swap does not amortize.

But in a multi-factor model, long rates and short rates can have a richer experience which implies that pay-down can occur when long rates are high as well as when they are low. Since the one factor approach will create simulated market conditions, which are less favorable to a fixed receiver, the fair price of a fixed receiver derived in this manner will be lower than in the multi-factor approach – they get less. In Wall Street parlance, one can say that a one-factor model over values the *short embedded optionality* in the swap. That is, there is an implied optionality that the swap writer (the dealer) owns which allows the dealer to amortize away the swap when it is in the interest of the dealer to do so. A one-factor model overvalues this optionality and thus undervalues the value of the deal to the fixed receiver.

Thus the two modeling approaches, one-factor and multi-factor, will come up with differing fair values. The one factor approach will under price a fixed receiving Indexed Amortizing Swap. When this market was created in the 90's, there were only a few players on the dealer side. One house was using a principal components analysis to price. They eventually changed their modeling approach as they learned the basics of pricing. Others were using the one factor approach. Bankers Trust was using an early two-factor model.

Bankers had large market share but eventually one dealer took most of the business. That dealer was using a one-factor model and mispricing deals but since the buy-side was receiving fixed and a one-factor model under prices, this dealer's market share increased. Eventually that dealer took major losses and had to mark down their books when reality came home to roost.

There is always a risk when market participants blindly use models they do not understand in both a practical as well as in a theoretical sense. This is an example of why the simplistic statement, "Pricing should be done according to accepted street standards …", which is often stated so blithely can be meaningless or even misleading.

The moral of this story is there are wrong ways to price derivatives and there are some right ways – some better than others. Complex derivatives may change their pricing over time because of modeling advances. The issues surrounding real derivatives pricing are subtle and just buying models may or may not be the solution in a given instance. Many hedge funds do not have the tools and have to depend on dealers for pricing. Many fund of funds, even if they had access to all underlying hedge fund positions, are not capable of separate pricing.

And then there is the issue of private equity. Funds that manage private equity are essentially venture capital funds investing in private companies. There is very definitely social value in this kind of investing and it should be encouraged. But putting a value on these kinds of positions is much more an art than it is a science.

Risk

Position level data does contain information on risk. But how much information and whether that information is valid depends, in part, on the strategy. For example, in the case of a statistical arbitrage fund[21], position data will contain less risk information because these funds tend to churn. True information on risk, relative to a particular stat arbitrage strategy, is embedded in the particular algorithm used. Nevertheless, position concentrations can provide an investor with a view on undiversified risk, concentration risk and liquidity issues even for a statistical arbitrage fund.

Risk systems that take positions as input and fully model them are more sophisticated and more robust than those that take a lesser form of information like returns or exposures or those that take positions but then just proxy the positions to some

[21] The term Statistical Arbitrage usually refers to some form of principal component analysis as applied to trading deviations around a basket of securities along with a system capable of efficient trade execution. But in recent years the term has been generalized and now can be used to refer to any statistical model based trading.

index. But assessing the risk of a position necessarily ignores the trading capabilities of the manager beyond the strategic capabilities implied by the snapshot of the static positions.

Consider this example. A manager replicates a short put option by trading the underlying stock. At any moment in time, the replicating portfolio consists of a long position in the stock (the option equivalent position), which is revealed to an investor. The investor has no information on the trading strategy – only on the position. The investor calculates the VaR at the 5% level for the stock using standard assumptions. Assume the stock has 30% volatility and the investor calculates the VaR at a one-month horizon. The VaR is expressed as a percent of the original stock price, which is assumed to be100. VaR on this long stock position will be about 13.7%[22]. And because the investor only has access to the position and not the strategy, the investor calculates risk as measured by VaR to be 13.7% - that is, there is 1 chance out of 20 that the portfolio can lose more than 13.7% in a month. Yet the VaR on a short put, struck at the money, with an implied vol of 30% and 2 months to expiration is about 184%[23].

Of course, things are not so simple – they never are. If we assume the manager's initial capital is equal to the value of the put and that the manager borrows the remainder required to fund the replicating stock position, then dollar VaR relative to actual initial capital, including leverage in the replicating position, becomes 184% for the option and 134% for the stock[24]. The stock VaR increases because the position is leveraged. See this example summarized in Example 1 below.

[22] One month percent VaR on a simple stock may be calculated roughly as: $1.645 * vol / \sqrt{12}$ and more exactly, based on the lognormal assumption, as: $1 - e^{-\left(.5*vol^2 \frac{1}{12} + 1.645*vol\sqrt{\frac{1}{12}}\right)}$

[23] The VaR on a short put can be evaluated analytically because the short put is a monotonic function of the underlying lognormally distributed price and the analytic solution is available for the VaR of the underlying.

[24] The exact assumptions used in this calculation are valuation date: Jan 14, 2003, horizon date for VaR: Feb 13, 2003, Option expiration: March 14, 2003 – 260 business days per year, no dividends, zero reinvestment rate, strike = underlying price = 100.

		VaR in percent	VaR in percent relative to value of put (initial equity equals put value and replicating stock position is levered)
Short a 2 month put on 1,000 shares struck at the money	$ 4,864		
5% VaR of short put	$ 8,971	-184%	-184%
Equivalent position in shares	$ 476		
Value of long stock position	$ 47,568		
5% VaR of long stock	$ 6,517	-13.7%	-134%

Example 1: Comparison of 1-month VaR between that on short put position and on equivalent position of underlying stock

It should be emphasized that VaR is only used in this example as a means of expressing risk. The result is not due to a deficiency in VaR. Whatever means used to assess risk would arrive at the same conclusion, which is that positions contain information on risk but the information is not complete, elements of strategy may or may not be included in the position information in varying degrees. Nevertheless positions do contain valuable information if one has the sophisticated tools required to extract it and if one understands the limitations and knows how to interpret the results.

Calculating Risk from positions

Assessing the risk embedded or implied by a position is subject to interpretation. Nevertheless, with sophisticated enough tools and personnel, position level risk assessment can be valuable – not only when looking at market risk but also credit, liquidity risk, fraud risk in pricing, etc.

Position level Risk Measurement is accomplished in two ways. One is *stress testing* and the other is *risk aggregation*. Stress testing means subjecting the portfolio to market stresses or scenarios and producing observations in the form of portfolio p&l. Thus one may ask what would happen to a particular portfolio if the Dow Jones Industrial Average falls by another 2,000 points or if interest rates increase by 200 basis points, or if there is a prolonged war in the Gulf. Stress testing is a useful measure but the types of stresses must be explicitly defined ahead of time. Market stress scenarios and the resulting risk measure can be assessed based on experience and econometric views. This is a powerful technique for a knowledgeable insider. It is not an easy tool to use to clarify and communicate generic overall risk for management committees, regulators and investors.

Risk aggregation measures refer to the use of some aggregate parameter that allows a reduction in the dimensionality of risk for ease of viewing and interpretation. All risk in a given portfolio, account or sub-account can be mapped into a single aggregate number. Examples of these kinds of aggregation measures are VaR, volatility, expected loss, downside volatility, etc. These statistical risk aggregation measures are all functions of portfolio p&l experienced over a universe of possibilities, each possibility probability weighted.

Aggregation over a portfolio of diversified risks is useful because it reduces the dimensionality of the problem to something a trader, portfolio manager, or management committee can conceptualize. That is the strength of aggregation risk measures.

Its weakness is the other side of the same coin: it leads to a reduction of dimensionality of the problem and therefore eliminates information. Obviously if the portfolio has ten distinct sources of risk and aggregation leads to one overall summary number, something is being lost in the process. There is no way to get around this. It is still useful to aggregate risk and conceptualize it in reduced dimensions. But the user of this information should be knowledgeable in the interpretation of that information.

The most robust approach for risk aggregation given position level information is probably based on the use of a full monte carlo simulation. A full simulation of the market based on underlying risk factors that have been identified as fundamental to the market is run[25]. Snapshots of the state of the market are generated over simulated time. Position valuations and mark to market can be evaluated dependent on simulated market states. This can be done many times and statistics can be drawn on the P&L of the positions. Risk and diversification effects can be calculated and expressed in terms of VaR or in alternative statistical terms. Risk measures can be tracked over real time. Changes will be noted. With sufficient drill down capability, a risk manager can analyze what has changed and why.

Another use of the position based monte carlo approach is in the creation of super-structures. That is, in the creation of a structured notes based on an underlying hedge fund or fund of fund. The structured note might be viewed as an option structure on an underlying that is defined by a hedge fund or a group of funds. The positions in the fund(s) form a basket of securities that defines the makeup of the fund. In this view, valuing an option on this structure or valuing a structured note is like valuing an option on a basket of securities defined by the fund's underlying positions. Theoretically, if the monte carlo is set up correctly, one should be able to calculate super-structure values and hedges.

Position level information provides a level of disclosure and a source for analytic risk assessment that is limited only by processing capabilities.

The Concept of Leverage

I used leverage in the section on survivorship bias and showed that given a survivorship bias framework, leverage impacted statistical risk measures like Sharpe Ratios and VaR. For the purposes of that study, leverage was used in a conceptually simple and well-defined way. I started with a certain amount of initial equity capital, say x. And then simulated borrowing of (n-1)*x more capital which was used to fund a position of total value n*x in a given asset.

[25] Examples of fundamental underlying risk factors are Par Swap Yields, spreads, fx rates, factors fundamental to the stock market, futures, etc.

This is referred to as a leverage of n to 1. If the asset has a return of r, then the leveraged position will experience a return of n*r. If the volatility of returns of the asset is vol, then the volatility of returns of the leveraged position will be n*vol. So in this special case, leverage and risk are linearly related.

Leverage may be defined intuitively as using borrowed money to increase exposure. Leverage allows magnification of returns through borrowing to increase asset holdings. The idea is to fund at a lower rate than the rate of return generated by investing the capital. Since a larger amount of capital is invested than the starting equity, exposure and risk are increased. The increase in risk is the price one pays for the increase in returns. This is an example of straightforward leverage. It does appear from these examples that leverage directly magnifies risk so when people say a fund is highly leveraged; they implicitly are also saying that there is additional risk. But things are not always what they seem.

Although the concept of leverage enters nearly any discussion on financial risk – especially when that discussion involves hedge funds, often real-world leverage is not so easy to calculate and it is not related directly to risk. A simple example is this: you could lever into a 5% volatility stock at 5 to 1 or, alternatively, use no leverage into a 90% volatility stock and the lower leverage would have the higher risk.

Here is a slightly more involved example of the complexities of interpreting and calculating leverage. Since the mark to market of a futures contract is zero, people often run into a wall when trying to calculate the leverage of a futures position. Even if initial margin is included in the calculation, the leverage seems so large and so diverges from any perception of risk that the concept seems flawed.

Consider **Table 4** below, which contains daily prices for stock X. An investor has initial equity of $600 and buys $600 of Stock X on 1/2/2003. The investor sells the stock at $662.50 on 1/16/2003 for a profit of $62.50. This is clearly a trade with no leverage, or stated differently, 1 to 1 leverage.

Now look at Table 5, which contains the history for a Eurodollars Futures contract. Suppose our investor goes long the futures contract and puts up $600 initial margin. At $25 a basis point[26], the resulting account value (variation margin plus initial margin[27]) on the trade is also displayed in Table 5 – compare the variation margin of the eurodollar contract to the price history of Stock X in **Table 4**. The investor unwinds the position on 1/16/2003 for $662.50 for a profit of $62.50.

Leverage is usually thought of as the ratio of the amount of money you control to initial equity capital. A Eurodollar Futures contract is indexed to one million dollars notional amount. You are trading the rate that will be paid on a future loan of one million dollars. Since $600 of initial margin was required to go long the futures contract and since the contract controls a notional amount of one million dollars, it appears that leverage is 1,000,000/600 = 1,667 to 1. Yet if you compare the price history of the stock, which was not leveraged in **Table 4** to the variation margin history of the Eurodollar Futures trade in Table 5, they are identical. Does leverage have any meaning in this case?

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[26] 25$ per 01 is the sensitivity of a standard Eurodollar futures contract on a 3-month rate. See http://www.cme.com/httpwrapper.cfm?wrap=/wrappedpages/clearing/spex/intrRateGroup.htm

[27] Maintenance margin can be less than initial margin but I am simplifying for the example

	Stock X
1/2/2003	$ 600.00
1/3/2003	$ 600.00
1/6/2003	$ 587.50
1/7/2003	$ 600.00
1/8/2003	$ 637.50
1/9/2003	$ 587.50
1/10/2003	$ 625.00
1/13/2003	$ 625.00
1/14/2003	$ 637.50
1/15/2003	$ 650.00
1/16/2003	$ 662.50

Table 4: Stock X price history

	March 2003 90 day Eurodollar Futures Contract	Variation margin on Eurodollar Contract given $600 initial margin
1/2/2003	98.635	$ 600.00
1/3/2003	98.635	$ 600.00
1/6/2003	98.630	$ 587.50
1/7/2003	98.635	$ 600.00
1/8/2003	98.650	$ 637.50
1/9/2003	98.630	$ 587.50
1/10/2003	98.645	$ 625.00
1/13/2003	98.645	$ 625.00
1/14/2003	98.650	$ 637.50
1/15/2003	98.655	$ 650.00
1/16/2003	98.660	$ 662.50

Table 5: March Euro$ history

There is a difference between these two positions, though it is not obvious from the price histories reproduced here. The difference is that the Eurodollar contract in Table 5 can produce negative account values because of the possibility of negative variation margin that is larger than the initial margin (resulting in a negative account balance). That cannot happen with the stock X price history in **Table 4**. Stock X bottoms out at a price of zero. The highest the indicative price of the Eurodollar contract can go is 100[28]. This means the maximum profit is (100.00-98.635)*2500 = $3,412.50, so the account value tops out at $4,012.50 – whereas the stock X account has no upper bound. So these trades are not actually identical. Still, does it make sense to say that the stock trade has no leverage and the Eurodollar trade is leveraged at 1,667 to 1? Maybe it does make sense to say it – but does it have anything to do with risk? Does leverage have any meaning when used for differing classifications of security types?

There is a way to make these trades look more identical or more analogous. Just short the futures contract[29]. Now losses are limited to when the futures contract prices at 100. Start with initial $3,412.50 equity capital to cover the possibility that the Eurodollar

[28] The rate on the Eurodollar contract is unlikely to go negative.

[29] Taking a short position in a Eurodollar Futures is no more involved than taking a long position. There is symmetry.

contract will go to 100. For the Eurodollar account, the investor can lose all initial margin and the account value can go to zero. For the analogous stock trade, the stock's value can go to zero[30]. Now whether we call it a stock history or a short Eurodollar futures variation margin history, it looks the same. See Table 6.

	Stock Y	
1/2/2003	$	3,412.50
1/3/2003	$	3,412.50
1/6/2003	$	3,425.00
1/7/2003	$	3,412.50
1/8/2003	$	3,375.00
1/9/2003	$	3,425.00
1/10/2003	$	3,387.50
1/13/2003	$	3,387.50
1/14/2003	$	3,375.00
1/15/2003	$	3,362.50
1/16/2003	$	3,350.00

Table 6: Simulated Stock Y price history obtained by shorting a March 2003 Euro$ Future and putting down $3,412.50 initial margin

Stock Y has the same risk (is identical) as the shorted Eurodollar futures plus variation margin and yet, there is no leverage in the Stock Y trade and there is $1,000,000/$3,412.50 = 293 to 1 leverage in the short Eurodollar futures trade.

Part of the problem with calculating leverage for a Eurodollar futures contract is that the 1,000,000 number used for the notional amount is really just a plug. These contracts are cash settled and the notional amount never comes into play except when it is used for calculating the $25 per basis point price sensitivity of the contract. In fact, there are 1-month serial CME Eurodollar contracts that are stated to have notional amounts of $3,000,000. But the reason for the $3,000,000 notional is just to keep the basis point sensitivity to $25. The length of the theoretical deposit underlying the 1-month futures contract is one-third the length of the theoretical deposit underlying the 3-month contract and so the notional has to be three times as large in order to preserve the basis point value.

If leverage were interpreted literally as the notional amount divided by initial margin, then for a given level of initial margin, the 1-month contract would have 3 times the leverage of the 3-month contract. And this conclusion is based on nothing more substantial than the value of a plug number used to create a fixed dollar basis point sensitivity. We can take this absurdity further. The following equation relates the notional amount associated with the theoretical deposit amount (or loan) underlying a Eurodollar futures contract to the term in months of that theoretical deposit.

[30] The upper bound on the simulated stock trade is so high (corresponds to 0 eurodollar indicative price) that it doesn't matter when setting up the analogous stock trade.

$$\frac{N}{10{,}000} * \frac{M}{12} = 25$$

$$N = notional\ amount$$

$$M = underlying\ term\ inmonths$$

Equation 1: Equation relating theoretical underlying notionals and terms for Eurodollar futures contracts with a fixed sensitivity of $25 per 01

Now we can pretend (thought experiment) that the notional N increases without bound while the term in months, M, decreases inversely to the notional amount so that our $25 per basis point equation is satisfied. In this case the notional can be anything we like – at least theoretically – without violating any fundamental law about how Eurodollar futures contracts are structured. But from our notion of leverage, this implies leverage can be anything we want it to be – it can be infinite – and yet we still have the same dollar sensitivity per basis point of the contract. In fact as the notional increases without bound, the maturity of the theoretical contract decreases without bound. A futures deposit or loan with a duration of a trillionth of a micro second isn't much of a term. In fact, it effectively doesn't exist. No real notional flows take place.

This thought experiment reasoning implies that there is really no reason at all for specifying a notional amount. Only the basis point sensitivity is fundamental and the notional amount is a needless fiction. But this implies that any concept of leverage when applied to Eurodollar futures is also meaningless if it is intuitively meant to capture the amount of capital controlled by a lesser amount of capital.

Leverage and Risk

It is often said that Leverage and risk are two different things. This may be true, but when the statement is made that a fund is highly leveraged, implicit in that statement is the perception that the portfolio is risky. The additional risk taken on as a consequence of leverage is a mixture of liquidity, credit risk and market risk.

Leverage seems like a simple and straightforward concept but it is difficult to define in an unambiguous way in all but the simplest of cases. Short positions or derivatives tend to obscure what is meant by leveraged assets and borrowed funds. A structured note whose payout is convoluted with embedded short optionality is effectively setting up a situation in which capital used to finance the note is implicitly raised by shorting the options embedded in the note. Breaking apart the note into assets and liabilities, in a way that makes sense from a leveraged point of view, is not so simple in the general case – especially when there are several sources of convoluted risk underlying the note.

The way in which leverage relates to risk is not clear even in simple situations and is subject to interpretation. Consider a very simple example in which you are long a volatile position and short a volatile position. You want to use leverage as a measure of some relative exposure that is clear and easy to understand. Ultimately, leverage should be indicative of how much volatile capital you control relative to original cash equity. The capital under control cannot simply be the difference between the long and the short. The answer could be zero, which would mean there is no aggregate volatile capital under control. Some people would add the absolute value of the two positions to obtain total volatile capital. But suppose the long and short positions *were* mirror images of one another, exactly in the same underlying, and netted each other out. In this case, there would be no residual risk and there would really be no volatile capital under control (idealized situation). Aggregation of leverage to obtain portfolio leverage in a meaningful, unambiguous, way is an obvious problem.

Leverage as a measure of relative exposure or as a measure of capital under control relative to equity is a muddled concept and cannot be unambiguously used as a risk indicator. Moreover, when muddled concepts are used in fundamental reasoning, that reasoning can become muddled in a magnified way – leveraged muddling.

For example, it has been stated in the literature that it is cheaper to obtain leverage through derivatives than through conventional means because less capital is committed. Often this is perceived to be the situation when the investor, money manager, or the corporate treasurer is acquiring a desired exposure by buying a derivative. They perceive themselves to be paying less for that leverage/exposure because they are ignoring the fact that embedded in the structure is optionality that they are implicitly short. The deal is being paid for with the embedded short optionality. They are paying with risk rather than with capital. And it may be that taking on leverage/exposure in this way is actually more expensive, not less, but this fact would only be obvious if they marked it to market (if they had the resources to mark to market). But off-balance-sheet accounting or another form of hand waving or the equivalent can be used to ignore the fact that the exposure is actually being paid for by taking on additional risk. Muddled concepts are themselves a source of risk.

Because leverage is a desired calculation but is somewhat nebulous, several definitions and ways of looking at leverage have arisen. There are two general classifications: accounting leverage and risk based leverage, and several sub-definitions within each of these classifications[31].

Basics of Leverage Math[32]

Equation 2:

The following equation is a basic leverage expression, one that agrees with the intuition that leverage directly magnifies returns.

Basic expression for Leverage:

$$L = \frac{\text{return on equity}}{\text{return on assets}}$$

Equation 2: can be rewritten as

[31] Sound Practices for Hedge Fund Managers – Feb 2000

[32] The sections on *Leverage Math* are a bit more mathematical than the rest of this paper. The less mathematically inclined (or less interested in math) reader can skip these sections.

$$L = \frac{\left(\frac{\text{change in equity value}}{\text{equity value}}\right)}{\left(\frac{\text{change in asset value}}{\text{asset value}}\right)}$$

But p&l from assets are moved into equity, which is the same as saying that if all assets are marked to market, and sold off; then pure equity remains and captures the sum total of p&l of all assets. So the change in equity value is the same as the change in asset value and:

Equation 3: $L = \frac{\text{asset value}}{\text{equity value}}$

This is the simplest expression of leverage and the one most commonly used.

At this point it might help to use some basic algebra to express these terms more concisely and see where the interpretation of leverage becomes cloudy and where intuition breaks. An investor has X_E dollars to invest. This is the investor's equity against which they borrow $X_L = (L-1) * X_E$ dollars, which is the present value of the liability. Assume everything is invested in one asset.

Equation 4: $X_A = X_E + X_L$.

The p&l on the asset is dX_A. If the position were liquidated, the p&l on the original equity would be $dX_E = dX_A$. Return on the asset is $\frac{dX_A}{X_A} = \frac{dX_E}{X_E + (L-1) * X_E} = \frac{1}{L} * \frac{dX_E}{X_E}$. Thus, as stated earlier:

Equation 5: $L = \frac{\left(\frac{dX_E}{X_E}\right)}{\left(\frac{dX_A}{X_A}\right)} = \frac{roe}{roa}$

There are several equivalent ways to write the equation for leverage. For example, $L = \frac{dX_E}{dX_A} * \frac{X_A}{X_E}$, which can be obtained by re-writing Equation 5. This expression can be used to calculate option (or more generally, derivative) leverage[33] with respect to the underlying asset, where $\frac{dX_E}{dX_A}$ is the option's hedge ratio. Also, if we think of the stochastic equity variable as a function of the stochastic asset variable and apply Ito calculus, we will obtain the well-known result[34] $L = \frac{dX_E}{dX_A} * \frac{X_A}{X_E} = \frac{\sigma_E}{\sigma_A}$. Where σ_E is the annualized volatility of equity (the volatility of the option's price) and σ_A is the annualized volatility of the asset underlying the option.

Also note that from the two equations, $X_L = (L-1) * X_E$ and $X_A = X_E + X_L$, we immediately have the result $L = \frac{X_A}{X_E}$ and the implication of this is $dX_E = dX_A$.

I summarize here the various common ways of expressing leverage (although this is not an exhaustive list[31]):

$$L = \frac{\left(\frac{dX_E}{X_E}\right)}{\left(\frac{dX_A}{X_A}\right)}$$

$$L = \frac{dX_E}{dX_A} * \frac{X_A}{X_E}$$

$$L = \frac{\sigma_E}{\sigma_A}$$

$$L = \frac{X_A}{X_E}$$

Equation 6: Alternative ways of expressing leverage

There are some conceptual analogies to be drawn between asset-liability analysis and the analytical approach of mathematical finance that may help shed the light of intuition on the above equations for some people. Equity is what you will end up with if the portfolio is un-wound. This is also the meaning of portfolio mark to market; so equity

[33]The representation of leverage as $L = \frac{dX_E}{dX_A} * \frac{X_A}{X_E}$ can be used to extract some meaning of leverage from simple derivatives like forwards and options - see IMF Working Paper, Measuring Off-Balance-Sheet Leverage, Peter Breuer, December 2000

[34] This result is well known and used often in Wall Street derivatives houses when one is interested in determining the volatility of a derivative in terms of underlying volatility. It can easily be derived by using Ito Calculus.

and portfolio mark to market are equivalent[35]. In the way the term 'asset' as used in Equation 4, the meaning is analogous to an underlying position in a portfolio. The liability is, in both cases, the funding component. The portfolio (or balance sheet) can be thought of like a derivative in which the underlying is the asset and the mark on the present value of the derivative is the equity. These analogies help when interpreting quantities, i.e., the term $\frac{dX_E}{dX_A}$ can be thought of as the delta of Equity (mark) with respect to the underlying asset (portfolio delta with respect to some asset, or option delta with respect to the underlying).

The problem with the definition(s) of leverage is that it becomes cloudy in a complex situation. Nevertheless, it has some meaning but must be interpreted within context. If it is used in the simplest way, as many portfolio measures of performance and risk are, it can easily mislead.

I can throw some light on the different approaches to leverage embodied by the alternative expressions in **Equation 6** by looking at the case of implied option leverage. (For an alternative approach that leads to the same equations, see IMF Working Paper, Measuring Off-Balance-Sheet Leverage, Peter Breuer, December 2000.)

Suppose you started with \$5.00 equity and you bought a 3-month European call option, struck at the money at \$100. The implied vol is 20%. To keep things simple, assume no dividends and a 0% interest rate. This option is worth (Black Scholes) \$4.00. If you take the option as an asset and use the expression for leverage that says $L = \frac{value\ of\ asset}{value\ of\ equity}$, you would calculate a leverage of 1. Whereas if you used the equation $L = \frac{dX_E}{dX_A} * \frac{X_A}{X_E}$, which, in this case, can be interpreted as

$L = (Hedge\ Ratio) * \frac{value\ of\ underlying\ equity}{value\ of\ call}$. If we plug in the numbers, we have $L = 0.52 * \frac{100}{4} = 13$.

The difference in perception of leverage based on these two difference calculations, 1 and 13, is because:

1 In the first calculation, we took the option as an asset and took its value as the asset value and since that was all we had in the portfolio, we saw the option as having a leverage of 1.

2 In the second calculation, we are calculating the magnification of returns experienced by holding the option instead of the stock. In this calculation, we are using the underlying stock as the asset and the option is like a portfolio that contains the stock.

[35] Some may disagree that equity is the same as mark to market valuation of a portfolio or balance sheet because of accounting rules that might allow non-mark to market valuation or because there is no market for some financial objects (i.e. expected earnings, etc.), but one can put a prudent valuation on anything as if it could be marked to market and it is in that spirit that a portfolio mark to market valuation is equivalent to balance sheet equity.

Holding an option is like holding a position in the underlying stock - the position is adjusted as the stock moves - plus holding a funding position. In our case, with a zero interest rate, we can ignore the funding. So at the level of stock price 100, the option is equivalent to holding 0.52 shares (hedge ratio) in the underlying stock for each share under option. The value of this position (value of asset) is $0.52*100. And the amount of equity it cost to hold this position is $4 (price of the option, the equity). Taking the ratio of asset value to equity results in leverage of 13. Based on this interpretation, the only thing that has changed is what we consider to be the underlying fundamental asset.

A more detailed analysis of leverage that encompasses more complex structures with short optionality and multiple sources of risk would require another paper. So I'll end the leverage discussion here so as not to lose focus. The idea is that when calculating leverage, you have to clearly identify what the underlying risks are that you are leveraging.

I read in a newspaper recently that there was an effort afoot to control leverage in hedge funds. This statement was made in an effort to control risk. My guess is any leverage controls could be gotten around because of the complexity of even measuring leverage and the effort would miss its mark.

Epilogue

Analysts, Risk Managers, Portfolio managers and investors who use statistical analysis without question or without understanding as to where the holes, ambiguities and weaknesses are - are taking on additional risks. This risk is not the same as market risk, or any of the other commonly thought of risks such as liquidity risk or credit risk or operational risk. They are taking on the risk of misuse of information. It is not mathematics that is at fault or the information itself. It is blind reliance on statistical technique that can lead to a false sense of security that is at fault. This blind reliance can come about for several reasons. One reason is practicality. The statement is often made that, "Something is better than nothing." That is often the case. Not always. Perhaps a broken screwdriver is better than no screwdriver at all, but only if you make special effort to use it correctly given the fact that it is broken. Another reason for misuse of information may be lack of experience or lack of pragmatic knowledge or just plane old naiveté.

Still another reason is to purposefully mislead in order to hide or misstate risk and to attract investor capital where the numbers are presented for only one purpose: to convince investors that there is a high level of sophistication at a particular operation. I have heard it said more than once that the only purpose of risk management is to attract investor capital. This is the most devious of the reasons for misuse of risk management technique – and the most dangerous.