Modern Portfolio Theory and Quantum Mechanics

GREGORY CURTIS

GREGORY CURTIS
is chairman of Greycourt & Co., Inc. in Pittsburgh, PA.
gcurtis@greycourt.com

The year 2002 marks the 50th anniversary of the publication of Harry Markowitz' seminal paper on mean variance optimization,[1] a then-obscure event which nonetheless inaugurated what we now know as modern portfolio theory (MPT). Over the following five decades, Markowitz and his followers[2] have contributed enormously to our understanding of the behavior of capital markets and of the nature of risk and its relationship to investment returns. MPT has, in a broad way, allowed us to model how markets are likely to behave over very long periods of time, and has therefore allowed us to base the design of investment portfolios on principles that are at least in some fundamental way related to likely market behavior. For investors born after MPT concepts were incorporated into real-world investment portfolios, it's hard to believe what a revolutionary change MPT has occasioned.[3]

The year 2002 also marks the 100th anniversary of Lord Kelvin's articulation of the atomic model, launching what we now know as quantum mechanics,[4] the branch of physics that deals with the behavior of matter and light at the atomic and subatomic scale. Like MPT, quantum theory has also proven to be both accurately descriptive—in this case of how particles behave in the natural microcosm—and also remarkably predictive, enabling scientists, for example, to predict the existence of infinitesimal[5] particles long before physical evidence of their existence could be detected. But physicists also understand that quantum mechanics has its limits. Under certain prescribed conditions—namely, the world of infinitely small particles—quantum mechanics "works." But events that occur at the level of the visible world we actually inhabit—the world of ants, humans, buildings, planets, solar systems, galaxies—are not merely events that fall several standard deviations outside what quantum theory would predict. Instead, they are events that have nothing whatever to do with quantum mechanics, but that are governed instead by very different rules that can be understood only by reference to very different theories. Indeed, the Holy Grail of physics these days is the attempt to construct a "unified theory," one that will reconcile quantum mechanics with relativity theory.

In this article, we examine selected limits to the usefulness of MPT and draw conclusions as to areas where other approaches are as likely as MPT to provide helpful insights to investors. We start with a review of the critical assumptions underpinning MPT and then review implications on important decisions such as the classification of asset classes, the use of anchor to windward in individual portfolios, the role and use of hedge funds, real estate, or hard assets, and the redefinition of risk.

MODERN PORTFOLIO THEORY

Modern portfolio theory is useful under certain prescribed conditions, some of which we know about and some of which we don't. We know, for example, that MPT assumes continuous pricing, a world in which markets are free, societies are free and stable, transaction costs are generally minimal, and investors are rational wealth-maximizers. Within that set of assumptions, MPT provides useful insights and tools to select an optimal portfolio along the "efficient frontier." Once that optimal portfolio is selected, investors are strongly advised to move as swiftly as possible[6] toward that portfolio and to maintain over time as close an ongoing mix of the various asset classes or strategies as the optimal portfolio specifies.

Several authors have suggested that such an approach is flawed for a variety of reasons. Horvitz [2002][7] focuses on periodic portfolio rebalancing and suggests that systematically moving back to that strategic balance may be neither realistic nor optimal. Brunel [1998, 2002][8] argues that MPT only has limited uses to a taxable investor, focusing on its inability to deal with "the cost of getting there" and "the cost of staying there," representing the frictional costs associated with a portfolio's initial position and the fact that relative differences in the performance of each strategy leads both to portfolio drift and to tax costs when it is rebalanced. Even more vividly, the world of behavioral finance has blossomed in response to our recognition that at least one of the prescribed conditions—that investors behave rationally—rarely holds true.[9]

In short, events that occur outside the conditions under which MPT remains valid are not merely events that fall several standard deviations outside what MPT would predict. More to the point, they are events for which MPT does not provide significant insight, as they do not respond to the principles proposed by MPT. Rather, they are governed by very different rules that can be understood only by reference to very different theories.

In addition to the fundamental issues of tax-efficiency, transaction costs, and behavioral considerations, we also know that other prescribed conditions are often absent. Prices are never—not rarely—continuous, for example,[10] and sometimes the discontinuity can be breathtaking. Consider Black Monday in October 1987, when, two-thirds of the way into an otherwise unremarkable year, a year in which the markets would ultimately rise 5%, the U.S. markets suddenly plummeted 23% *in one day*. Viewed in modern portfolio theory terms, this event simply cannot be understood. Indeed, financial economists have calculated that,

> on the basis of the market's historic volatility, had the market been open every day since the creation of the universe, the odds would still have been against [the market's] falling that much on a single day. In fact, had the life of the universe been repeated *one billion times*, such a crash would still have been theoretically "unlikely."[11] [Emphasis in the original.]

Two standard deviations, indeed!

Or consider an especially sophisticated German investor who, just after World War I, designed his portfolio in accordance with the tenets of MPT, carefully balancing German large, mid-, and small-cap stocks with a sensible allocation to German bonds and a reasonable allocation to international stocks. By the end of the Weimar Republic in 1933, our savvy investor would have been bankrupt.[12] His mistake was to assume that MPT governed all events in the capital markets, when in fact, under the conditions of post-World War I Germany, MPT was completely irrelevant.

MPT professionals proceed on the assumption that financial theories, like physics theories, must be formulated in terms of numbers, equations, and mathematics. But mathematical analyses only provide an abstract framework within which scientific conclusions can be drawn without direct reference to the actual reality of the capital marketplace. And that actual reality is not merely quirky and messy, it is a reality that frequently behaves according to rules quite different from, and bearing no relation to, the elegant but sterile equations of the MPT gurus.[13]

The point of all this is simply that, while modern portfolio theory is an essential tool in the design and management of intelligent portfolios, it cannot be blindly relied upon for the simple reason that market events will occur, and with alarming frequency, which have nothing to do with MPT. MPT holds such sway in the United States because, by a considerable margin, U.S. stock prices are the most continuous, its markets are the most free and efficient, U.S. society is the most free and stable, and U.S. investors are the most knowledgeable and rational in the world. Elsewhere around the world these conditions are largely or wholly absent, and investors in those parts of the world would be foolish, indeed, to own MPT-designed portfolios. But even in America our stock prices are not

truly continuous (see above), our markets are not perfectly free and efficient (witness insider trading, questionable accounting practices, conflicted analysts, corrupt executives), U.S. society is not perfectly free and stable (witness race riots, terrorist attacks, controlled markets for many goods and services), and U.S. investors are not perfect wealth-maximizers (consider day-trading, the bubble markets of the late 1990s, the dot.com foolishness, and the huge difference among virtually all investors between their *theoretical* time horizons and risk tolerance and their *real* time horizons and risk tolerance).

IMPORTANT IMPLICATIONS

What are the implications of recognizing the limits of modern portfolio theory? The main implication is that advisors who rely blindly on MPT to design client portfolios are ill-serving those clients. Such portfolios will work well when the special conditions relevant to MPT are operable, but will perform very poorly—indeed, potentially disastrously—on the frequent occasions when those conditions are inoperable. Financial advisors must understand that events will occur in the capital markets that are not predictable by—indeed, that are irrelevant to —MPT, and hedge client portfolios accordingly. In particular, advisors to capital preservation or absolute return-oriented investors,[14] like most families, need to give at least as much consideration to worst-case outcomes as to computer-generated "efficient" portfolios.

Let's consider some specific examples of how a blind reliance on MPT approaches to portfolio design can wreak havoc, and how non-MPT approaches can work in investors' interests:

1. *Developed versus emerging markets.* As this article is written, it is becoming cutting-edge opinion that the traditional distinction between developed and emerging markets is artificial and should be eliminated. To some extent this is nothing more than a marketing ploy: Investors who are terrified of emerging markets and would not consider investing in them may in fact invest in emerging economies if that money is part of an overall international allocation. In other words, the impact of the emerging markets exposure is heavily diluted—and therefore largely invisible—and so the investor goes along with it. But viewed from the point of view of the limits of modern portfolio theory, this cutting-edge opinion is dangerous. MPT largely works in developed markets because the special conditions required are largely present. But in most emerging markets few or none of those conditions are present: Capital markets are largely not free, emerging societies are neither democratic nor stable, and investors—both local and foreign—rarely behave rationally in the face of the frequently bizarre behavior of those markets and societies. Hence, MPT concepts largely prevail in developed international markets and are largely irrelevant to the behavior of international emerging markets.[15] As a result, the distinction between these two asset classes needs to be preserved.
2. *Anchors to windward.* Recently, we advised a family who had become enormously wealthy as the result of the sale of their company for cash. Aside from investing that cash wisely, our first advice was to take a significant piece of the capital, invest it in a very solid, core fixed income portfolio, and surround that portfolio with a sophisticated asset protection strategy. No tenet of modern portfolio theory would have suggested such a strategy, and no soundly-designed asset allocation model would have demanded such a move. Our advice was informed in part by principles of behavioral finance, of course, but it was also the result of our recognition that MPT concepts simply don't operate at many times and in many places for reasons that no one fully understands, and that this fact of investment life should be acknowledged in this particular client's portfolio.
3. *Treasury bonds for taxable investors.* Sophisticated advisors sometimes recommend that wealthy investors own non-callable, long-term Treasury bonds even though a soundly constructed portfolio of intermediate-term municipal bonds would generate more after-tax income with lower price volatility. In part, such a recommendation results from the recognition that the strategy represents the only assured hedge against a deflationary economic environment. More broadly, however, it is a recognition that MPT concepts don't apply in many kinds of unusual market environments, one of those being deflationary markets.
4. *Hedge funds.* For the better part of a decade, and in rare cases for much longer, investors who have constructed thoughtfully diversified hedge fund portfolios have achieved something quite remarkable: equity-like returns with bond-like price volatility.[16] According to MPT, this is impossible: Risk and return must be positively related. An

MPT-friendly explanation of this phenomenon might go something like this: Hedge fund investment results are a transitory phenomenon resulting from the obscurity of hedge funds until recently; as more and more investors and money managers enter the hedge fund world, returns will decline, volatilities will rise, or both.[17] An MPT-unfriendly explanation might go something like this: Talented managers can hedge out directional market risk (hence the bond-like volatility) while still identifying promising investment opportunities (hence the equity-like returns).

5. *Asset returns.* Everyone "knows" that stocks generate 10% to 12% annual compound rates of return over time, while bonds will generate considerably less and cash even less than bonds. The reason we "know" this is because of the good work of Roger Ibbotson and Rex Sinquefield, who have produced very accurate reports on *Stocks, Bonds, Bills and Inflation*[18] beginning with the year 1925, updating the numbers annually. In addition, the theoretical underpinning of modern portfolio theory supports analytically what the actual results suggest empirically. We have already addressed some of the issues surrounding overreliance on MPT in designing portfolios, but let's also take a look at problems with the actual numbers:

   - First, it is important to acknowledge that the Ibbotson/Sinquefield numbers are the best we have and, as with MPT generally, we would be foolish not to work with them in our portfolio design work. That said, the question is how confident we should be in those numbers, an issue that will affect the portfolios we recommend to our clients.
   - On this subject, the "strong" version of MPT would argue that returns of 10% to 12% are core investment wisdom, that there is something inherent in the ownership of a diversified portfolio of large company stocks that produces such returns over time. The "weak" version of MPT would acknowledge that absolute levels of returns are unknowable (based on this data), but that over time stocks will outperform bonds which will outperform cash. Investors would do well to adhere to the "weak" version.[19]
   - Although three-quarters of a century may seem like a long time, it's actually a relatively short period of time in terms of the degree of confidence we can have that the Ibbotson/Sinquefield data have much useful predictive power. There are simply not enough observations in a 75-year period to allow us to say with confidence that the next 75 years will turn out the same way.
   - If 75 years isn't a long period of time confidence-building-wise, consider the time horizon of the typical wealthy family. Most families design portfolios for 10-to 20-year periods,[20] but in virtually no 10-to 20-year period did U.S. large caps produce 10% to 12% returns. Sometimes they produced more, sometimes less. Over periods of time that short, it's anybody's guess. (And, as noted above, there is a considerable difference between most families' theoretical time horizon—the 10 to 20 years referred to above—and their actual time horizon—about 36 months.)

6. *Hard assets.* Many families own so-called "hard" assets: gold, timber, crude oil, directly placed real estate, etc. Advisors sometimes treat these assets as though they were no different than other investment assets—that is, that they have expected rates of return, price volatilities, and correlations with other assets—and design the portfolio accordingly. But hard assets are best viewed as true hedges against MPT-designed portfolios, not as a part of them. Applying MPT concepts to gold-as-an-asset-class (for example) is like applying quantum mechanics concepts to black holes.
7. *"Fat tails."* Financial advisors sometimes casually note that while their models assume a normal distribution of events, in practice "fat tails" are often encountered.[21] But a distribution that has fat tails is by definition not a normal distribution, and the consequences for the management of real-world portfolios of this casual fact are momentous.
8. *Risk.* In modern portfolio theory terms, the risk associated with owning capital assets is measured by the price volatility of those assets. In some ways, that makes perfect sense, but in other ways it is simply too silly for words. To see why, let's look at volatility in a different context: the risks associated with weather. Imagine that climatological scientists were to argue that weather risk could be defined by the volatility—that is, the changeability—of weather.

In some ways, that makes sense. Whether the weather is good or bad, if it is consistent enough that we can plan ahead for it, then we can deal with the risks. But if volatility is too high—if weather changes from good to bad to good too frequently and unpredictably—then we can't plan ahead. But this is almost a trivial consideration—what really matters is the risk of extremely damaging weather: hurricanes, tornados, lightning, powerful thunderstorms, hail, etc. And the same is true for the price volatility of investment assets: the natural, and even occasionally extreme, oscillations in the price level of securities should be a trivial consideration for most investors. We know from long experience that good markets follow bad and vice versa, just as good weather follows bad, and vice versa. What really matters is that we not employ strategies that destroy capital so permanently as to change fundamentally the investor's economic circumstances. Such strategies are easy to identify and avoid, although, unfortunately, many investors fail to avoid them:

- Significant capital can, and very likely will, be *rapidly* destroyed by a) holding concentrated positions in individual securities or industries, no matter how sound those companies seem today;[22] b) getting caught up in bubble markets or trendy investment themes (dot.coms, day trading, tech, telecom, momentum stocks, etc.); and c) structuring a portfolio that contains far more imbedded risk than we can tolerate, so that you bail out immediately after incurring large losses.
- Significant capital can, and will, be *slowly* (but equally surely) destroyed by a) owning a portfolio that is too cautious relative to our spending; b) not paying attention to the costs of investing: (in this order) taxes, transaction costs (including market impact), and advisory fees; and c) constantly changing our investment strategies.

Sortino[23] and Harlow[24] took a different tack to look into this issue, investigating the concept of using downside risk as a superior measure relative to the traditional standard deviation. Others propose to use simulations and alternative definitions of risk to inject life into the concept of standard deviation. For instance, consider the option of using the expected return and risk of a possible portfolio to derive probabilities that the portfolio will return less than a certain minimum return over some period of time or even produce negative rolling returns over one, three, or even five years. Despite the conceptual limitations associated with the assumption that returns are normally distributed, such an analysis might allow an individual to evaluate the probability that his or her definition of a hurricane or tornado will hit the portfolio. Similarly, appropriately designed multi-path simulations will provide an opportunity for investors to preview a number of the potential trajectories their wealth might follow over time and judge whether they are or are not comfortable with the implied ride.

Finally, it is important to note that standard deviation, the measure of risk preferred under MPT, is also at best incomplete. Investors are indeed subject to price volatility as a risk, but a number of other risks are not captured by the concept of standard deviation. Brunel,[25] among others, mentions liquidity risk (the risk that certain strategies require assets to be committed for specified periods of time and cannot be liquidated at will), decision risk (the risk of changing one's mind—and one's strategy—at the point of maximum pain), agency risk (the risk of being different from one's friends or acquaintances), counterparty risk (the risk associated with the continued solvency of brokers and other intermediaries through and with whom one executes investment decisions), or regulatory risk (the risk that a strategy currently employed in a taxable portfolio will become unacceptable).

SUMMARY

Though modern portfolio theory represents the best thinking we have on the way capital markets behave and are likely to behave in the future, one must remember that MPT is far from perfect. It is therefore essential that we employ MPT concepts in our financial advisory work. But there will be frequent instances when it doesn't work well for reasons that are well understood (irrational investors, chaotic societies, flawed structural assumptions) and for reasons that aren't (the Crash of 1987). Consequently, all financial advisors, but most especially advisors to wealthy families, for whom significant losses of capital are catastrophic events, must approach modern portfolio theory and its uses in portfolio design work very carefully.

ENDNOTES

[1]Harry Markowitz, "Portfolio Selection." *Journal of Finance*, 1952.

[2]Among the more prominent contributors to MPT were James Tobin, Franco Modigliani, Merton Miller, William Sharpe, Robert Merton, Myron Scholes, and Eugene Fama.

[3]These days, when we encounter financial advisory firms that still manage money in pre-MPT ways—mainly stockbrokers, trust companies, and regional banks, where individual relationship officers still (amazingly) buy stocks and bonds for their clients—they seem almost amusingly quaint, anachronisms that demonstrate the truth of the adage that it is impossible to underestimate the intelligence of the average investor.

[4]Many physicists will be surprised to learn that 2002 marks the 100th anniversary of quantum theory. More likely dates for the theory's origin would be 1897 (Thompson's discovery of the electron), 1900 (Max Planck's development of the concept of the "quantum," or fundamental increment of energy), 1905 (the year of publication of Einstein's three seminal papers on the photoelectric effect, the special theory of relativity, and statistical mechanics), 1913 (Niels Bohr's proposal of the quantitative shell model of the atom), or even 1926 (Heisenberg's uncertainty principle). Unfortunately for these gentlemen, I needed a year that ended with a "2."

[5]The term "infinitesimal" is relative, of course, but by way of example a single cubic centimeter of air contains roughly 10,000,000,000,000,000,000 atoms.

[6]See Scherer, Bernhard. "Cost Averaging—Fact or Myth?" *The Journal of Private Portfolio Management*, Winter 1998, pp. 18-21.

[7]Horvitz, Jeffrey. "The Implications of Rebalancing the Investment Portfolio for the Taxable Investor." *The Journal of Wealth Management*, Fall 2002.

[8]Brunel, Jean L.P. "Why Should Taxable Investors Be Cautious When Using Traditional Efficient Frontier Tools?" *The Journal of Private Portfolio Management,* Winter 1998, pp. 35-50. Brunel, Jean L.P. "Integrated Wealth Management: The New Direction for Portfolio Managers." Institutional Investor Books, 2002, chapters 11 and 12, pp. 183-211.

[9]For an overall summary of the issue see Brunel, Jean L.P. "Integrated Wealth Management: The New Direction for Portfolio Managers." Institutional Investor Books, 2002, chapter 2, pp. 33-47. For more detail, see Kahneman, Daniel, and Mark W. Riepe. "Aspects of Investor Psychology." *The Journal of Portfolio Management*, Summer 1998, pp. 52-65. Shefrin, Hersh. "Irrational Exuberance and Option Smiles." *Financial Analysts Journal*, Vol. 55, No. 6, November/December 1999, pp. 91-103. Shefrin, Hersh. "Recent Developments in Behavioral Finance." *The Journal of Private Portfolio Management,* Summer 2000, pp. 25-37. Shefrin, Hersh, and Meir Statman. "The Disposition to Sell Winners Too Early and Ride Losers Too Long: Theory and Evidence." *Journal of Finance*, 40 (1985), pp. 770-790. Statman, Meir. "Behavioral Finance: Past Battles, Future Engagements." *Financial Analysts Journal*, Vol. 55, No. 6, November/December 1999, pp. 18-28. Statman, Meir. "Lottery Players/Stock Traders." *Financial Analysts Journal*, Vol. 58, No. 1, January/February 2002, pp. 14-21.

[10]Consider as one minor example the need to price securities at an arbitrary moment in time—the "close of business." In an era when securities are traded virtually 24/7, this alone injects an element of arbitrariness and discontinuity into securities pricing. *Understanding Tracking Error: Advanced Comments*, research brief, Parametric Associates (1999), page 2, note 3.

[11]These calculations were prepared by Jens Carsten Jackwerth and Mark Rubinstein, "Recovering Probability Distributions from Option Prices," *Journal of Finance*, 51, no. 5 (December 1996), p. 1612. The illustration was cited by Roger Lowenstein in *When Genius Failed* (Random House, 2000), p. 72.

[12]By that date hyperinflation gripped the German economy. Prices rose hourly and at the end it cost 1 billion German marks to send a letter to the U.S. Capitalizing on public outrage and resentment against the terms imposed on Germany by the Allies after World War I, Hitler came to power in 1933 and promptly suspended the Weimar constitution.

[13]One possible reason why modern portfolio theory is simultaneously an elegant explanation of market behavior under a set of very simple rules and also completely clueless about market behavior under most real-world conditions is this very insistence on explanation-by-mathematics. It makes financial economics seem more scientific—more like physics and less like psychology, for example—but it misses the big picture: MPT cannot explain much of what happens in real, operating markets and simply avoids such questions. But investors must place their capital at risk in real markets, not abstract frameworks. One possible way out of this dilemma has been proposed by physicist Stephen Wolfram, who, working with relatively simple cellular automata (patterns created by simple computer programs), has managed to create enormously complex systems that are not necessarily continuous or smooth, but that look remarkably like living, breathing stock markets. Stephen Wolfram, *A New Kind of Science* (Wolfram Publishers, 2002, pp. 429-432).

[14]If the S&P 500 Index is down 25% and the domestic equity portfolio is down 20%, a relative return investor is happy, but an absolute return investor is distinctly unhappy.

[15]I don't mean to imply that investors should avoid emerging markets, or any other markets where MPT concepts rarely operate. I do mean to imply that investors who put money into emerging markets expecting that MPT concepts of risk and return will prevail are likely to be sorely disappointed. Note that since the MSCI Emerging Markets Free Index was constructed, emerging markets returns have not begun to compensate investors for their risks (S.D.), another clue that something other than MPT is going on here. Another important point is that, as American-influenced free markets' ideas have permeated the world, the number of "emerging" markets has declined and the number of "developed" markets (or quasi-developed markets) has increased.

[16]For a discussion of this apparent inconsistency, see Brooks, Chris, and Harry M. Kat. "The Statistical Properties

of Hedge Fund Returns and Their Implications for Investors." Unpublished working paper, University of Reading, U.K., October 2001; or, Brunel, Jean L.P. "Absolute Return Strategies Revisited." *The Journal of Wealth Management,* Spring 2002, pp. 63-75. The principal insight is that the fact that the distribution of hedge fund returns is not "normal" but rather highly "kurtotic" (fat tails) and "skewed" leads investors to seek a higher Sharpe ratio as compensation for the greater risk inherent in hedge funds that surprises will be both bad and substantial.

[17]Actually, I agree that something like this MPT-friendly outcome is highly likely to occur. A huge amount of inexperienced money is pouring into hedge funds, with the result that new-and-unsophisticated hedge fund investors and rapacious-but-inexperienced hedge funds-of-funds vendors are likely to be bitterly disappointed in their investment results. But I also believe in the MPT-unfriendly argument: Thoughtful investors working with talented hedge fund managers will continue to achieve very un-MPT-like results.

[18]Ibbotson, Roger, and Rex Sinquefield. *Stocks, Bonds, Bills and Inflation 2000 Yearbook* (Ibbotson Associates, 2000).

[19]It may seem inconceivable that, over a long span of time, bonds could outperform stocks. But imagine a world in which the yields on stocks rose significantly (before the 1950s, stock yields were always higher than bond yields) and in which equity investors demanded some sort of senior claim on the assets of the corporation (say, by restricting its borrowing power). Such a world may not be a likely one, but it is a possible one, and in it bonds might well outperform stocks. It is also interesting to note that between 1800 and 1900 stock and bond returns were close: 6.51% for stocks and 4.99% for bonds. It was only in the 20th century that stocks significantly outperformed bonds: 9.89% for stocks and 4.85% for bonds. Jeremy Siegel, *Stocks for the Long Run*, cited by William Bernstein in *Only Two Centuries of Data*, Morningstar.com (July 30, 2002). For additional comments on this topic, also see Wilson, Jack W., and Charles P. Jones. "Long-Term Returns and Risk for Bonds." *The Journal of Portfolio Management*, Spring 1997, pp. 15-28; Jones, C.P., and J.W. Wilson. "Probabilities Associated with Common Stock Returns." *The Journal of Portfolio Management*, Fall 1995, pp. 21-32; Jones, C.P., and J.W. Wilson. "The Incidence and Impact of Losses from Stocks and Bonds." *The Journal of Private Portfolio Management*, Summer 1998, pp. 31-40.

[20]The "objective" time horizon for most multi-generational families is actually much longer than this. However, the *actual* time horizon for many family investors is much shorter. After observing family investors in action for nearly 30 years, it is clear to me that for many families invested during very difficult market periods (1973-74 and 2000-01, for example), the true time horizon is less than three years.

[21]In a perfectly normal distribution, two-thirds of all observations fall within one standard deviation. Two standard deviations (actually, 1.96 S.D.'s) would encompass 95% of all observations, and so on out to an infinitely rare set of observations at the tail end of the curve (on each side). But when we plot real-world capital markets events we don't get a normal distribution. Instead we get a distribution with "fat tails" on both ends of the curve. What this means is not that standard deviation methodology is fundamentally right but slightly wrong. What it means is that standard deviation is not the correct measurement of risk in the real world because the real-world distribution of events is not "normal."

[22]Whenever I mention this to people, they always point out the (very rare) exceptions: Wouldn't a reputable consultant have advised the early Microsoft employees to diversify their Microsoft positions? By holding onto that one stock, they became millionaires. Well, yes and no. Consultants would rarely advise diversifying completely away from a concentrated position in which the client has confidence. In the exceptional cases (like Microsoft), diversifying enough of the position to insure future wealth regardless of what happens to the company will result in investors being less rich than they would have been, but still very rich. In all the other cases, diversifying a portion of the position will avoid a possibly catastrophic loss of capital.

[23]Sortino, Frank A., and Robert Van Der Meer, "Downside Risk." *The Journal of Portfolio Management*, Summer 1991, pp. 27-32; Sortino, Frank A., and Hal J. Forsey. "On the Use and Misuse of Downside Risk." *The Journal of Portfolio Management*, Winter 1996, pp. 35-42.

[24]Harlow, W.V., III. "Asset Allocation in a Downside-Risk Framework. "*Financial Analysts Journal*, Vol. 47, No. 5, September/October 1991, pp. 28-40.

[25]Brunel, op.cit., note 9, Chapter 7, p. 115ff.