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con · sil'i · ence, *n.* [con- + salire to leap]
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A Tail of Two Worlds

Fat Tails and Investing

"[Victor Niederhoffer] looked at markets as a casino where people act as gamblers and where their behavior can be understood by studying gamblers. He regularly made small amounts of money trading on that theory. There was a flaw in his approach, however. If there is a…tide...he can be seriously hurt because he doesn't have a proper fail-safe mechanism."

George Soros
Soros on Soros (1995)[1]

"In statistical terms, I figure I have traded about 2 million contracts…with an average profit of $70 per contract. This average profit is approximately 700 standard deviations away from randomness, a departure that that would occur by chance alone about as frequently as the spare parts in an automotive salvage lot might spontaneously assemble themselves into a McDonald's restaurant."

Victor Niederhoffer
The Education of a Speculator (1997)[2]

"On Wednesday Niederhoffer told investors in three hedge funds he runs that their stakes had been 'wiped out' Monday by losses that culminated from three days of falling stock prices and big hits earlier this year in Thailand."

David Henry
USA Today (October 30, 1997)

"Much of the real world is controlled as much by the 'tails' of distributions as by means or averages: by the exceptional, not the mean; by the catastrophe, not the steady drip; by the very rich, not the 'middle class.' We need to free ourselves from 'average' thinking."

Philip Anderson
Nobel Prize Recipient, Physics
Some Thoughts About Distribution in Economics[3]

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Experience Versus Exposure

In his 2001 letter to shareholders, Warren Buffett distinguishes between experience and exposure. Although Buffett's comments are in the context of Berkshire Hathaway's insurance business, his point is valid for any exercise with subjective probabilities. Experience, of course, looks to the past and considers the probability of future outcomes based on occurrence of historical events. Exposure, on the other hand, considers the likelihood—and potential risk—of an event that history (especially recent history) may not reveal. Buffett argues that in 2001 the insurance industry assumed huge terrorism risk without commensurate premium because it was focused on experience, not exposure.

Investors, too, must discern between experience and exposure. The high-profile failures of Long Term Capital Management and Victor Niederhoffer give witness to this point. Remarkably, however, standard finance theory does not easily accommodate extreme events. Financial economists generally assume that stock price changes are random, akin to the motion of pollen in water as molecules bombard it.[4]

In a triumph of modeling convenience over empirical results, finance theory treats prices changes as independent, identically distributed variables and generally assumes that the distribution of returns is normal, or lognormal. The virtue of these assumptions is that investors can use probability calculus to understand the distribution's mean and variance, and can therefore anticipate various percentage price changes with statistical accuracy. The good news is that these assumptions are reasonable for the most part. The bad news, as physicist Phil Anderson notes above, is that the tails of the distribution often control the world.

Tell Tail

Normal distributions are the bedrock of finance, including the random walk, capital asset pricing, value-at-risk, and Black-Scholes models. Value-at-risk (VaR) models, for example, attempt to quantify how much loss a portfolio may suffer with a given probability. While there are various forms of VaR models, a basic version relies on standard deviation as a measure of risk. Given a normal distribution, it is relatively straightforward to measure standard deviation, and hence risk. However, if price changes are not normally distributed, standard deviation can be a very misleading proxy for risk.[5]

In fact the research, some done as long as 40 years ago, shows that price changes do not follow a normal distribution. Figure 1 shows the frequency distribution of S&P 500 daily returns from January 1979 to March 2002 and a normal distribution derived from the data. Figure 2 highlights the difference between the actual returns and the normal distribution. Analysis of different asset classes and time horizons yield similar results. [6] The figures show that:

- Small changes appear more frequently than the normal distribution predicts.
- There are less medium-sized changes than the model implies (roughly 0.5 to 2.0 standard deviations).
- There are fatter tails than what the standard model suggests. This means that there are a greater-than-expected number of large changes.

Figure 1: Frequency Distribution of the S&P 500 Daily Returns (1979-2002)

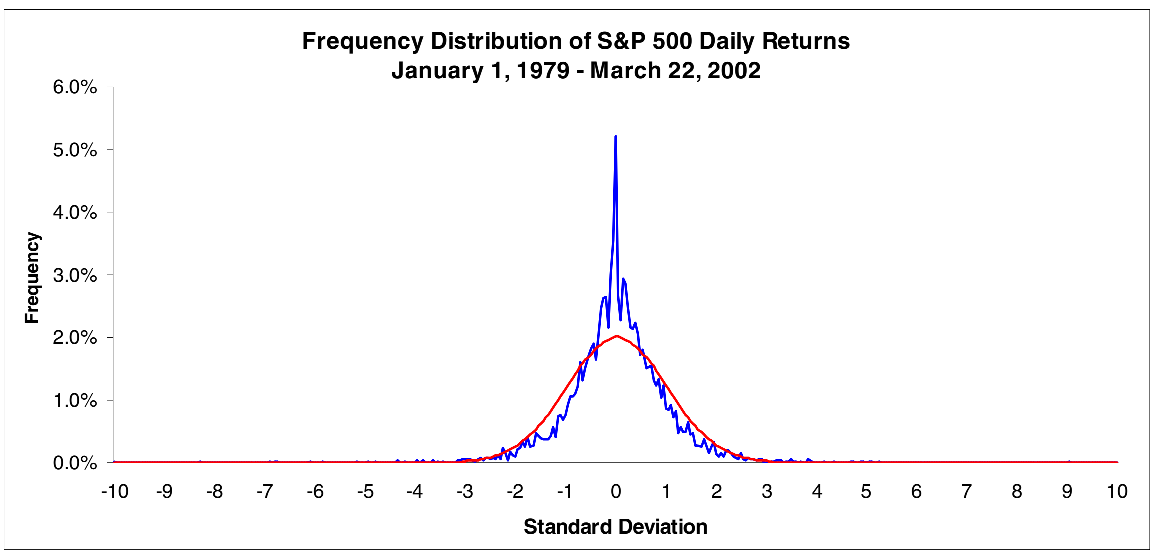
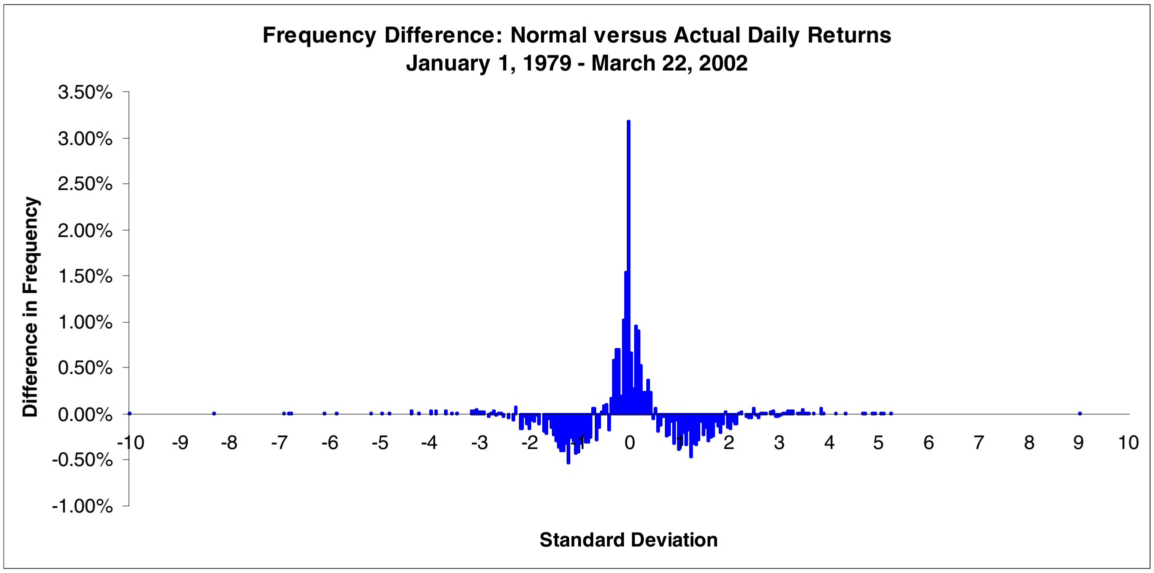


Figure 2: Frequency Difference



The fat tails, in particular, warrants additional comment. These extreme value changes happen considerably more frequently than the standard model suggests, and can have a substantial influence on portfolio performance—especially for leveraged portfolios. For example, during the October 1987 crash, which we excluded from our figures for presentation purposes, the S&P 500 plummeted over 20%, a change that is 19 standard deviations from the mean. Roger Lowenstein notes:

> "Economists later figured that, on the basis of the market's historical volatility, had the market been open every day since the creation of the Universe, the odds would still have been against its falling that much in 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'." [7]

The pattern of many small events and few large events is not unique to asset prices. Indeed it is a signature of systems in the state of "self-organized criticality." Self-organization is the result of interaction between individual agents (in this case investors) and requires no leadership. A critical state is one where small perturbations can lead to events of many types. Self-organized criticality marks systems as varied as earthquakes, extinction events, and traffic jams.[8]

Is there a mechanism that can help explain these episodic lunges? We think so. As we have noted in previous reports, markets tend to function well when a sufficient number of diverse investors interact.[9] Conversely, markets tend to become fragile when this diversity breaks down and investors act in a similar way (this can also result from some investors withdrawing). A burgeoning literature on herding addresses this phenomenon. Herding is when a large group of investors make the same choice based on the observations of others, independent of the own knowledge. Information cascades, another good illustration of a self-organized critical system, are closely linked to herding.[10]

What Fat Tails Mean for Investors

O.K. Big changes in prices appear more frequently than they are supposed to. What does this mean for investors from a practical standpoint? We believe there are a few important implications:

- *Cause and effect thinking*. One of the essential features of self-organized critical systems is that the size of the perturbation and resulting event may not be linearly linked. Sometimes small-scale inputs can lead to large-scale events. This dashes the hope of finding causes for all effects. For example, in a widely cited 1989 paper, Cutler, Poterba, and Summers review the 50 largest post-war moves in the S&P 500 Index and the "causes", as reported by the New York Times the subsequent day. They summarize:

  "On most of the sizable return days…the information that the press cites as the cause of the market move is not particularly important. Press reports on subsequent days also fail to reveal any convincing accounts of why future profits or discount rates might have changed." [11]

- *Risk and reward*. The standard model for assessing risk, the capital asset pricing model, assumes a linear relationship between risk and reward. In contrast, nonlinearity is endogenous to self-organized critical systems like the stock market. Investors must bear in mind that finance theory stylizes the real world data. That the academic and investment community so frequently talk about events five or more standard deviations from the mean should be a sufficient indication that the widely used statistical measures are inappropriate for the markets.

- *Portfolio construction*. Investors that design portfolios using standard statistical measures may understate risk (experience versus exposure). This concern is especially pronounced for portfolios that use leverage to enhance returns. Many of the most spectacular failures in the hedge fund world have been the direct result of fat tail events. Investors need to take these events into consideration when constructing portfolios.

A useful means to navigate a fat-tailed world is to first measure the current expectations underlying an asset price, and then contemplate various ranges of value outcomes and their associated probabilities. This process allows investors to give some weight to potential fat tail events.[12]

Standard finance theory has advanced our understanding of markets immensely. But some of the theory's foundational assumptions are not borne out by market facts. Investors must be aware of the discrepancies between the theory and reality and adjust their thinking (and portfolios) accordingly.

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[1] George Soros, *Soros on Soros* (New York: John Wiley & Sons, 1995), 17.

[2] Victor Niederhoffer, *The Education of a Speculator* (New York: John Wiley & Sons, 1997), ix.

[3] Philip W. Anderson, "Some Thoughts About Distribution in Economics," in W. B. Arthur, S. N. Durlaf and D.A. Lane, eds., *The Economy as an Evolving Complex System II* (Reading, MA: Addison-Wesley, 1997), 566.

[4] This process is know as Brownian motion. Albert Einstein pointed out that this motion is caused by random bombardment of heat excited water molecules on the pollen.

[5] See http://www.gloriamundi.org/var/varintro.htm.

[6] Edgar E. Peters, *Fractal Market Analysis* (New York: John Wiley & Sons, 1994), 21-27.

[7] Roger Lowenstein, When *Genius Failed: The Rise and Fall of Long-Term Capital Management* (New York: Random House, 2000), 72. Lowenstein is quoting Jens Carsten Jackwerth and Mark Rubinstein, "Recovering Probability Distributions from Option Prices," *The Journal of Finance*, 51, no. 5, December 1996, 1612. Jackwerth and Rubinstein note that assuming annualized volatility of 20% for the market and a lognormal distribution, the 29% drop in the S&P 500 futures was a 27 standard deviation event, with a probability of 10^{-160}.

[8] Per Bak, *How Nature Works* (New York: Springer-Verlag, 1996).

[9] Michael J. Mauboussin and Kristen Bartholdson, ''A Process for Outperformance," *The Consilient Observer*, 1, no. 6, *Credit Suisse First Boston Equity Research*, March 26, 2002.

[10] Sushil Bikhchandani and Sunil Sharma, "Herd Behavior in Financial Markets," *IMF Staff Papers*, 47, no. 3, 2001. See http://www.imf.org/External/Pubs/FT/staffp/2001/01/bikhchan.htm.

[11] David M. Cutler, James M. Poterba, and Lawrence H. Summers, "What Moves Stock Prices?" *The Journal of Portfolio Management*, Spring 1989.

[12] Michael S. Gibson, "Incorporating Event Risk into Value-at-Risk" *The Federal Reserve Board Finance and Economics Discussion Series*, 2001-17, February 2001. See http://www.federalreserve.gov/pubs/feds/2001/200117/200117abs.html.

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