Study of Fat-tail Risk

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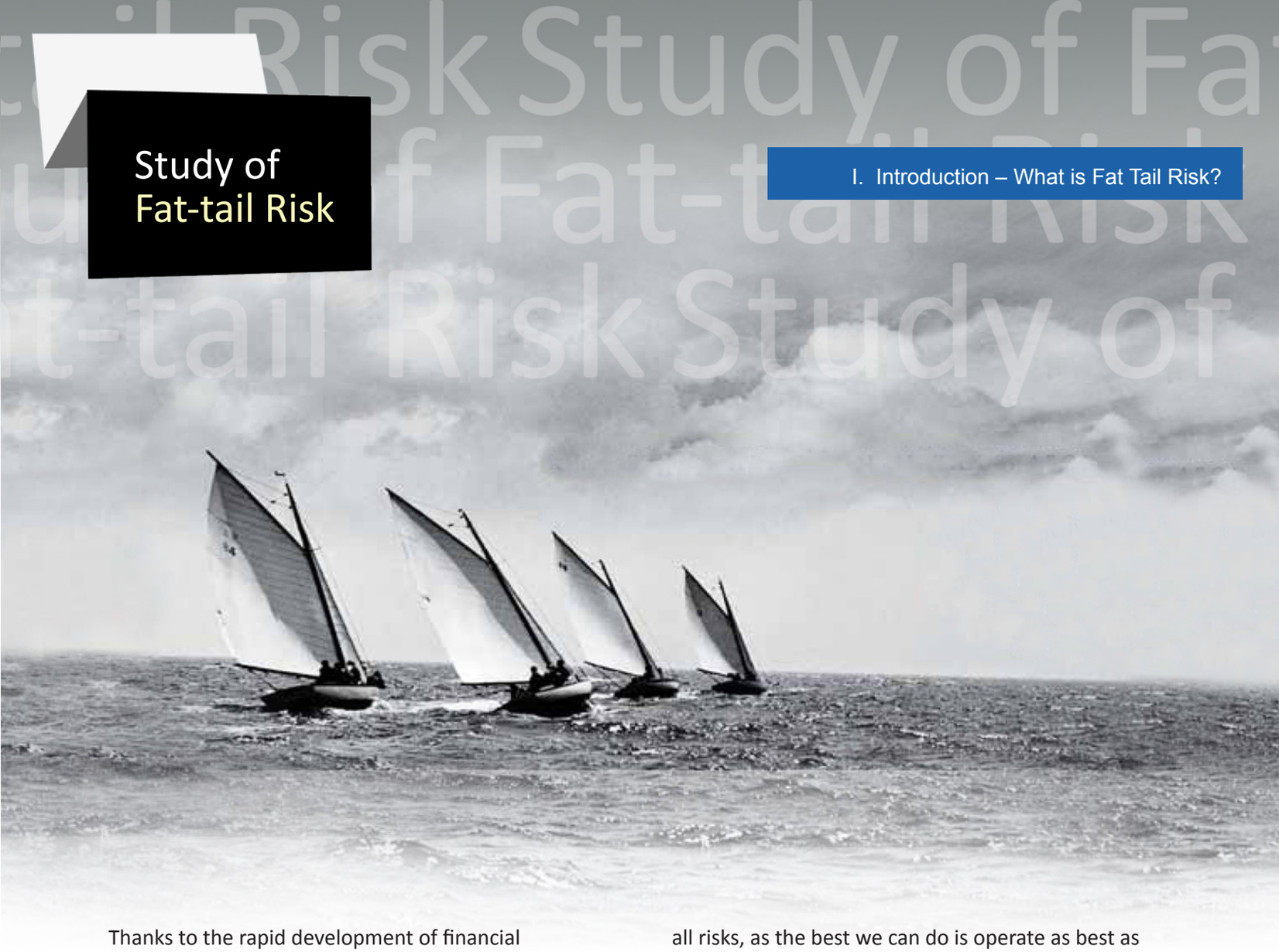
I. Introduction – What is Fat Tail Risk?



Thanks to the rapid development of financial engineering, investors have become better equipped at managing predictable portfolio risks. However, throughout the history of finance, there have been a number of extreme, and often severe, events that simply cannot be predicted based on prior events. These "tail risks" get their name from either side of a probability distribution curve, where tails represent decreasing probability as the curve approaches its two extremes. In his Black Swan theory, Nassim Taleb famously challenged the prevailing notion that these tail risks were just that: extreme cases that were highly improbable. The revised view of increased probabilities of extreme events is more widely known as "fat-tail risk".

The tail risks in question encompass a myriad of different possible triggers and outcomes. Conceptually, they can range from a terrorist attack to "fat finger" errors on the trading floor to an unexpected change in financial regulation. In terms of outcomes, all such events can present serious consequences for investors. Most unsettling of all is the reality that one can never fully guard against all risks, as the best we can do is operate as best as possible while being cognizant of these fat tails.

Especially during periods of financial inclemency, investors often look to ride out the storms in vehicles that will protect their assets and preserve their net worth. In the extraordinary events of 2008, there were few (if any) safe harbors, as virtually all asset classes with any risk attached suffered a perfect storm of bad news. Within the hedge fund industry, 2008 saw a large share of all hedge fund managers – at least 20% of over 10,000 – go out of business. By definition, hedge funds take long and short positions in various securities, and often "enhance" the performance with leverage. By using leverage, a diminutive arbitrage can yield magnificent returns. Conversely, leverage will multiply the damage from even the smallest mistakes: a fact many tend to forget – particularly times like now, when the system is awash with cheap money. It is therefore especially pertinent for hedge fund managers (and by association their investors) to carefully study and monitor the dangers of a fat-tail risk reality.

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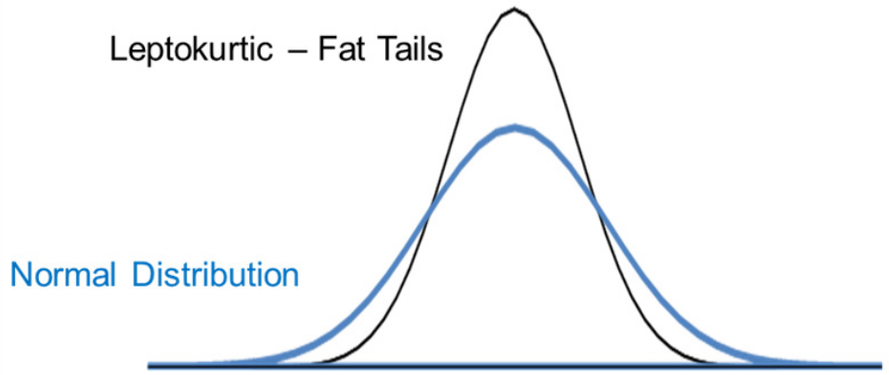
We define fat tail as a property of probability distributions exhibiting extremely high kurtosis, or "peakedness" of a curve, relative to the ubiquitous normal distribution (itself is an example of an exceptionally thin tail distribution). In academic terms, the condition of probability distribution that exhibits fat tail(s) is called leptokurtosis. A fat-tail risk in financial markets refers to extreme swings in the markets which cannot be predicted solely based on the normal distribution of the return probability.

Chart 1: Leptokurtosis vs. Normal Distribution



Sigma, or σ, is used as a parametric standard deviation of the S&P Daily Return Data. In this example, σ is the average daily deviation from the expected return of the market. We define a fat-tail event as one in which the daily market return exhibits a movement in excess of four standard deviations (or a "four sigma" event).

For our analysis of fat-tail risk in the U.S. stock markets, we used the S&P 500 Index's daily returns (the S&P Daily Return Data) from December 30, 1927 through November 5, 2010 (Source: Bloomberg)[1]. As most investors know, the S&P 500 Index is an asset-weighted stock index commonly used as a broad representative of U.S. stock markets.

[1]The S&P 500 index was created in 1957, but it has been extrapolated back in time. The first S&P index was introduced in 1923. Prior to 1957, the primary S&P stock market index consisted of 90 companies, known as the "S&P 90, and was published on a daily basis. A broader index of 423 companies was also published weekly. In order to capture the movement of broader stock markets than the Dow Jones Industrial Average, which is an index of 30 companies, the S&P index was chosen for the analysis of this paper.

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III. Methodologies

To illustrate the presence of fat-tail risk in the U.S. stock markets, two different methodologies were conducted. The first methodology is to calculate the daily returns of the S&P 500 Index and to compute statistics to examine whether the actual distribution of returns exhibits statistical characteristics of leptokurtosis.

The second methodology is to compare the frequencies of distributions falling into certain ranges of daily returns. The distribution range, or the Daily Return Range, is based on the distance from the mean, which is calculated as the number of standard deviations from the mean, or σ.

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Table 1 shows the statistics of the S&P data, including mean (0.03%), standard deviation (1.18%), kurtosis (18.35) and skewness (-0.10). The kurtosis – again, a measure of peakedness – of a normal distribution is 0, meaning the kurtosis of 18.21 for the S&P is indicative of a more variable, wider shaped distribution, i.e. the distribution has "fat tails". The skewness is a measure of asymmetry in the distribution curve, with negative skewness in the S&P indicating that the curve has a longer left (or negative-bias) tail. In plain English, this means that not only are there more days in which there are extreme movements in the S&P, *there are also a greater number of extreme negative daily returns* than extreme positive daily returns.

Table 1: Descriptive Statistics for S&P Daily Return Data (1927 ~ 2010)

Sample Number	20,811
Mean	0.028%
Standard Deviation	1.194%
Kurtosis	17.525
Skewness	-0.0964
Maximum Daily Return	16.610%
Minimum Daily Return	-20.467%

Based on the statistic in Table 1, we classified the S&P Daily Return Data into 13 categories as shown in Table 2. The more +/- 6σ events that we observe, the more evidently fat-tail risk exists in the S&P Daily Return. We also define an observation whose Daily Return Range exceeds 4 standard deviations from the mean as a fat-tail day.

Table 2: S&P Daily Return Data – Standard Deviation Ranges

# of Standard Deviations from Mean	Range of Daily Market Returns
+6σ	Above +7.19%
+5σ	+6.00% ~ +7.19%
+4σ	+4.80% ~ +6.00%
+3σ	+3.61% ~ +4.80%
+2σ	+2.42% ~ +3.61%
+1σ	+1.22% ~ +2.42%
0σ	-1.17% ~ +1.22%
-1σ	-2.36% ~ -1.17%
-2σ	-3.56% ~ -2.36%
-3σ	-4.75% ~ -3.56%
-4σ	-5.94% ~ -4.75%
-5σ	-7.14% ~ -5.94%
-6σ	Below -7.14%

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Under the statistical normal distribution of performance returns, deviations from the mean return should occur with a certain frequency; the larger the deviance, the lower the frequency. Table 3 shows that for the daily performance of the S&P 500, the normal distribution significantly underestimates the probability of having days with very significant negative returns, which we define as being four or more standard deviations from the mean. As an example, whereas the normal distribution of the daily return of the S&P would suggest a negative three-sigma event (between -3.56% and -2.36% daily returns) should have occurred 27 days over the last one hundred years, this has actually occurred over a hundred times in the 81 years since 1927. When one looks at even greater negative return days, the results become even more pronounced. As one will see from the chart below, the "normal" likelihood of a negative four-sigma event (between -4.75% and -5.94% daily returns) is one day every one hundred years; yet we have seen this take place an astounding 44 times since 1927. The same normal distribution suggests virtually zero possibility (.00003%) of a day where losses are greater than 5.94%, but, once again, we have witnessed such days on 40 occasions in the last 81 years, and alarmingly, four times in 2008 alone.

Table 3: S&P Daily Return Data – Actual vs Normal Distribution

	Actual Distribution		Normal Distribution	
# of Standard Deviations from Mean	Observed	Percentage	Predicted	Percentage
+6σ	25	0.12%	0	0.00%
+5σ	17	0.08%	0	0.00%
+4σ	30	0.14%	1	0.00%
+3σ	99	0.48%	27	0.13%
+2σ	286	1.37%	445	2.14%
+1σ	1,417	6.81%	2,828	13.59%
0σ	16,994	81.66%	14,207	68.27%
-1σ	1,416	6.80%	2,828	13.59%
-2σ	342	1.64%	445	2.14%
-3σ	101	0.49%	27	0.13%
-4σ	44	0.21%	1	0.00%
-5σ	18	0.09%	0	0.00%
-6σ	22	0.11%	0	0.00%
Total	20,811	100%	20,811	100%

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Charts 2 and 3 are graphical presentations of the actual and normal distribution of the S&P Daily Return Data. Chart 2 illustrated the peakedness of the observed data (green area) relative to the normal distribution. Meanwhile, Chart 3 exhibits the relative frequency of extreme, negative events compared to that predicted by the bell curve.

Chart 2: Actual S&P Daily Returns vs Normal Distribution

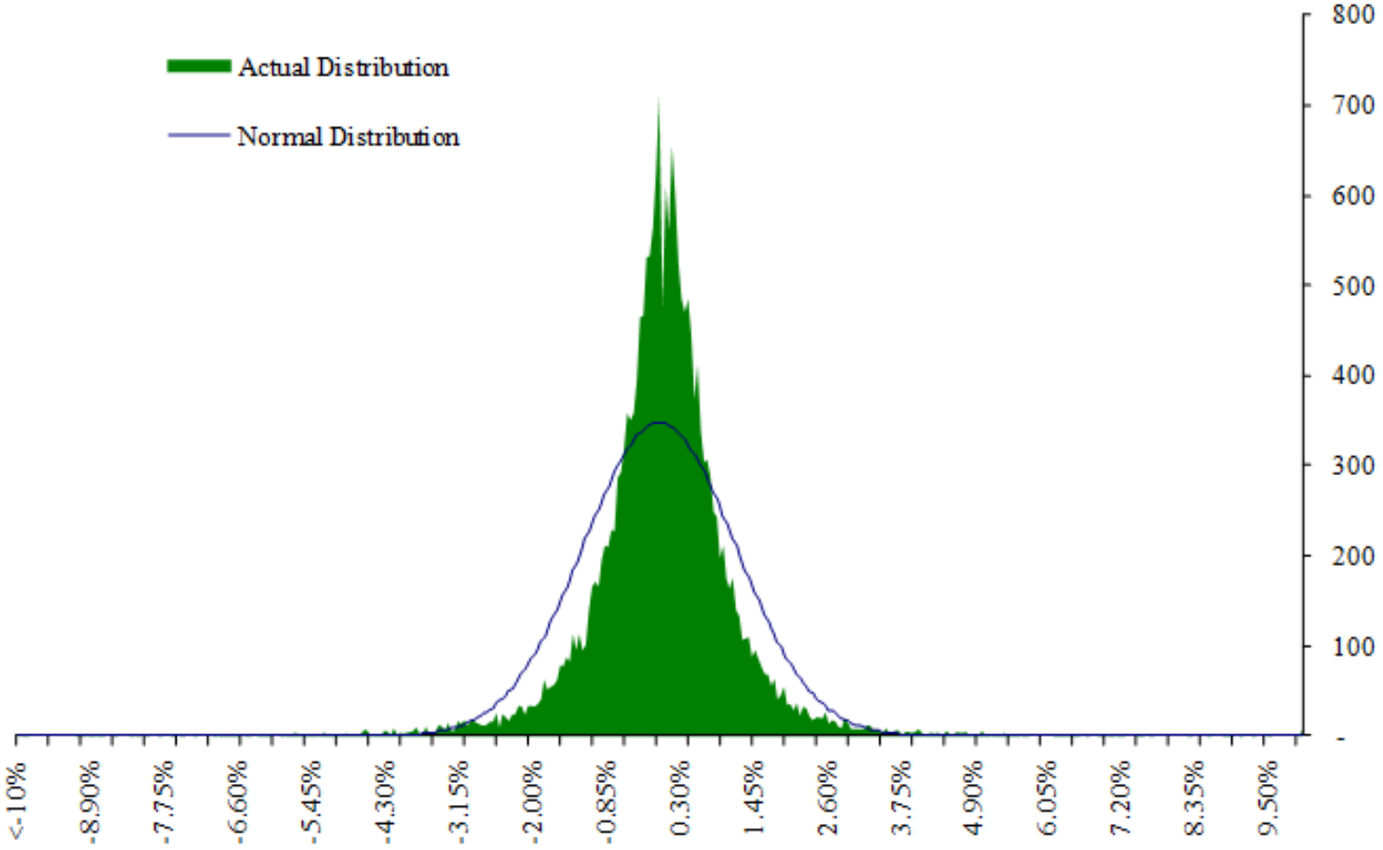

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Chart 3: Actual S&P Daily Returns vs Normal Distribution (from -3% to -10%)

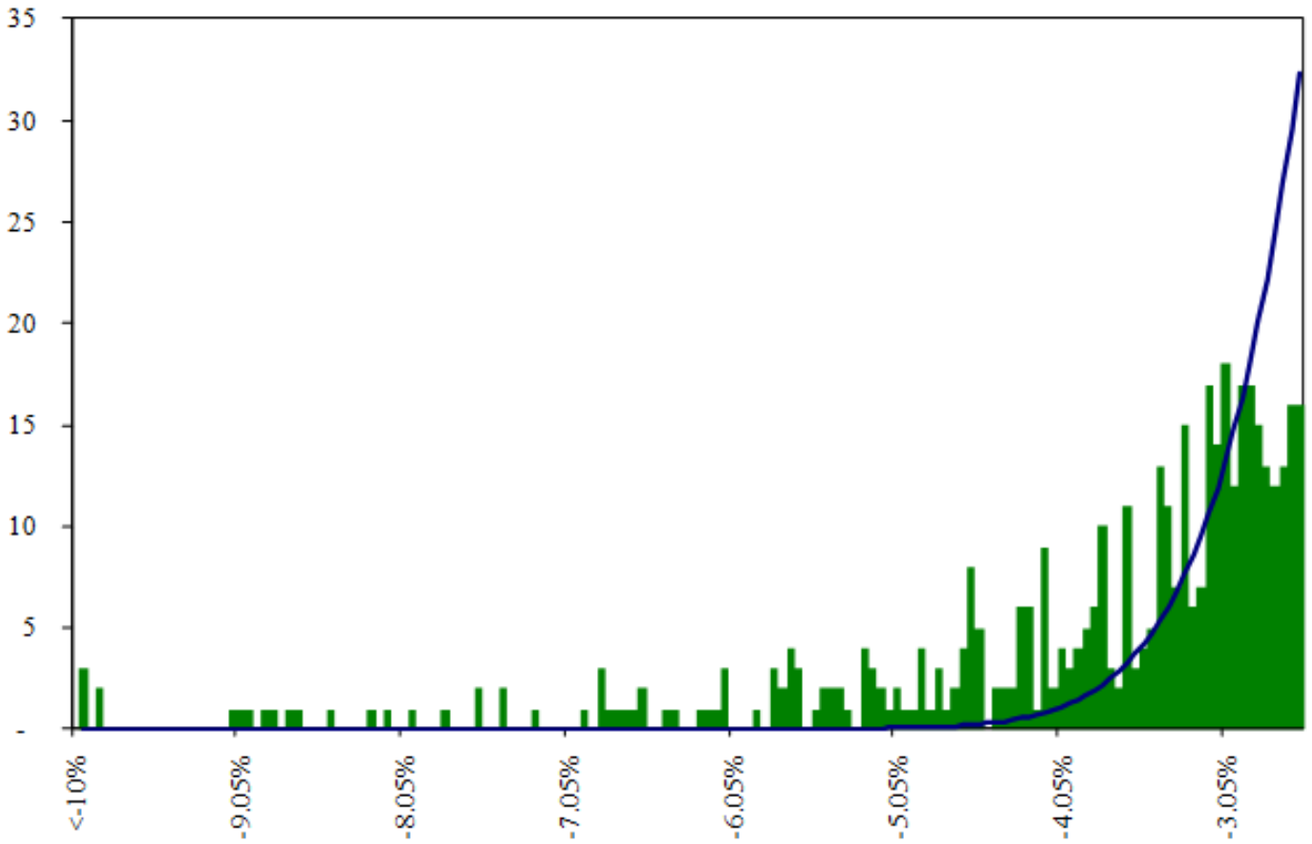

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Table 4 shows the historical trend of the fat-tail risk by decade within the data set. In addition to the frequency of fat-tail days, one can also observe their uneven distribution over time. During the period of 1930 ~ 1939, when the US economy suffered a severe economic slump, or the Great Depression, there is a higher frequency of fat-tail events.

Table 4: S&P Daily Return Data - Decade-by-Decade Analysis

		-4σ Daily Return		-5σ Daily Return		-6σ Daily Return	
Decade	Return	Days	%	Days	%	Days	%
1927 ~ 1929	21.46%	5	1.002%	1	0.200%	3	0.601%
1930 ~ 1939	-41.91%	25	1.002%	7	0.280%	11	0.441%
1940 ~ 1949	34.75%	3	0.120%	1	0.040%	2	0.080%
1950 ~ 1959	256.70%	1	0.040%	1	0.040%	0	0.000%
1960 ~ 1969	53.72%	0	0.000%	1	0.040%	0	0.000%
1970 ~ 1979	17.25%	0	0.000%	0	0.000%	0	0.000%
1980 ~ 1989	227.40%	2	0.079%	2	0.079%	2	0.079%
1990 ~ 1999	315.75%	0	0.000%	2	0.079%	0	0.000%
2000 ~ 2009	-24.10%	8	0.318%	3	0.119%	4	0.159%
2010 YTD[2]		0	0.000%	0	0.000%	0	0.000%
Total		44	0.211%	18	0.086%	22	0.106%
Normal Distribution			0.003%		0.000%		0.000%

After the 20% stock market crash on October 19, 1989, best known as Black Monday, the U.S. stock market grew for an entire decade while experiencing zero fat-tail event days. Even the first trading day after the September 11 terrorist attacks, the market rose 4.9%, a -4σ daily return. This relatively "quiet" market environment changed meaningfully in 2008.

[2]While major market indices suffered massive intraday losses on May 6, 2010 in the "Flash Crash", the S&P 500 (as a broad index) had recovered most of its losses by market close. Our data set excludes intraday performance.

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Triggered by subprime mortgage losses, the global financial system collapsed, and financial activity slowed significantly. A number of financial institutions failed, were acquired, or had to be bailed out by the government. The stock market was not an exception. As shown in Table 5, there was a significant increase in the frequency of fat-tail days and, as of November 2010, the only year with the same frequency of such events is 1932, in the midst of the Great Depression.

Table 5: S&P Daily Return Data - Selected Year Analysis

		-4σ Daily Return		-5σ Daily Return		-6σ Daily Return	
Selected Year	Return	Days	%	Days	%	Days	%
1932	-14.78%	8	3.200%	2	0.800%	4	1.600%
2008	-38.49%	4	1.581%	3	1.186%	4	1.581%
1929	-11.91%	5	2.008%	1	0.402%	3	1.205%
1931	-47.07%	2	0.794%	0	0.000%	2	0.794%
1933	44.08%	5	2.066%	4	1.653%	2	0.826%
1987	2.03%	1	0.395%	0	0.000%	2	0.791%
1930	-28.48%	1	0.398%	0	0.000%	1	0.398%
1934	-4.71%	1	0.402%	0	0.000%	1	0.402%
1937	-38.59%	4	1.600%	0	0.000%	1	0.400%
1940	-15.09%	2	0.797%	1	0.398%	1	0.398%
1946	-11.87%	1	0.400%	0	0.000%	1	0.400%
1998	26.67%	0	0.000%	1	0.397%	0	0.000%
2009	23.45%	2	0.794%	0	0.000%	0	0.000%
2000	-10.14%	1	0.397%	0	0.000%	0	0.000%
All		37	0.827%	12	0.285%	22	0.513%
Normal Distribution			0.003%		0.000%		0.000%

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Similarly, Table 6 shows the list of -6σ days since 1927. Prior to 2008, and with the exception of Black Monday, all -6σ Days were observed between 1920 and 1940.

Table 6: -6σ Days in History

Date	Daily Return
10/19/1987	-20.47%
10/28/1929	-12.94%
10/29/1929	-10.16%
11/6/1929	-9.92%
9/3/1946	-9.91%
10/18/1937	-9.12%
10/5/1931	-9.07%
10/15/2008	-9.03%
12/1/2008	-8.93%
7/20/1933	-8.88%
9/29/2008	-8.79%
7/21/1933	-8.70%
10/10/1932	-8.55%
10/26/1987	-8.28%
10/5/1932	-8.20%
8/12/1932	-8.02%
7/26/1934	-7.83%
6/16/1930	-7.64%
10/9/2008	-7.62%
5/14/1940	-7.47%
5/31/1932	-7.45%
9/24/1931	-7.29%

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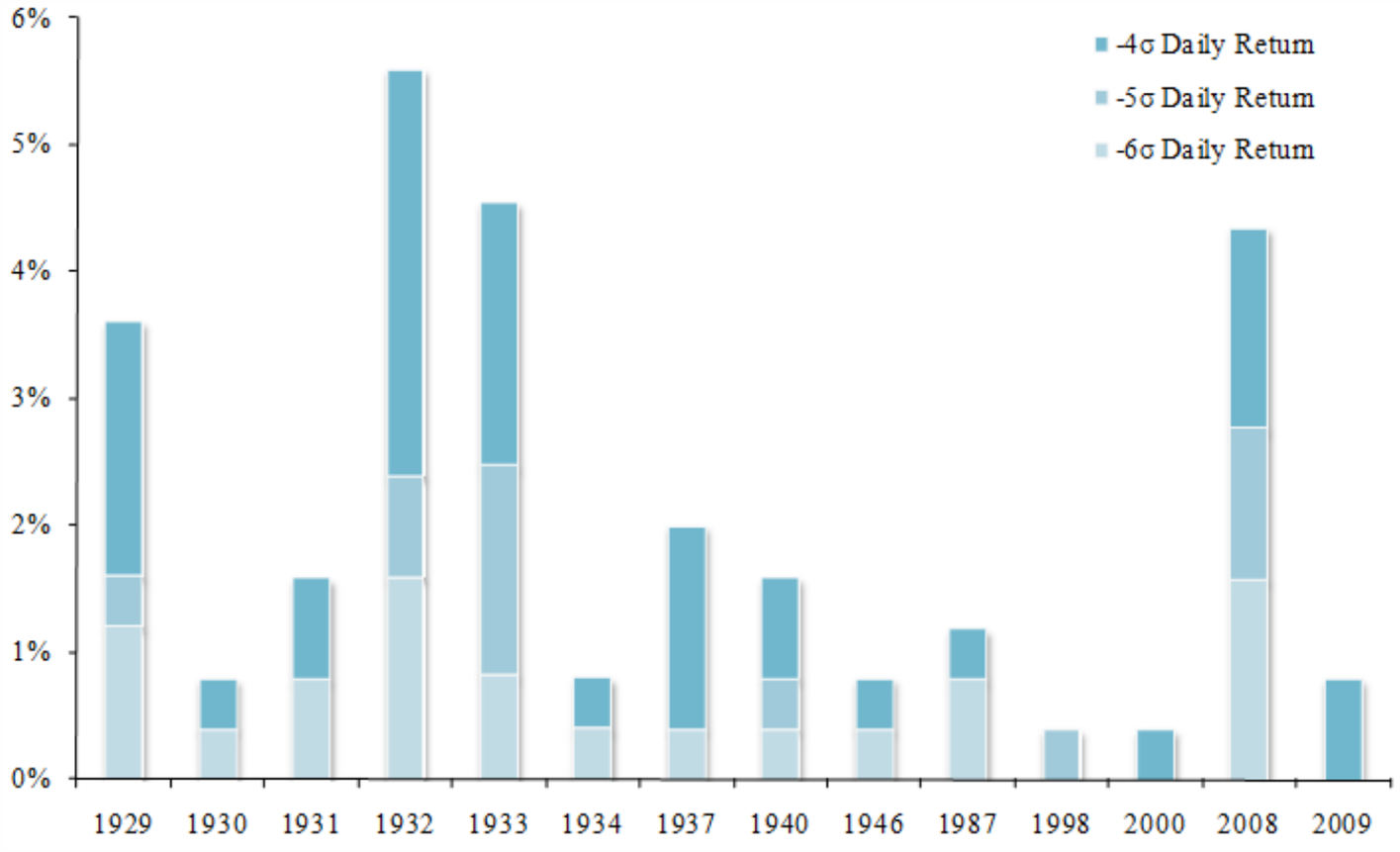
Chart 4 is a graphical representation of fat-tail days in selected years. As discussed above, a high frequency of fat-tail days was also observed in the 1930s.

Chart 4: Frequency of Extreme Events in Selected Years



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VI. Conclusion

The purpose of this paper is to examine, both conceptually and in hard numbers, the term fat-tail risk and study its existence in the context of the U.S. stock market. When compared to a normal distribution, historical data has shown a significant degree of fat-tail risk in the returns of the S&P Daily Return. As such, this study has shown that the stock market has experienced a far more volatile trading and market environment than assumed by a simple bell-curve (normal distribution).

Many investors believed that the Great Depression was a historical anomaly and that the volatility experienced by the stock markets during that period would not occur again, at least not with such frequency. The market conditions since 2008 have shown movements that are as extreme, if not more, than what was experienced over 70 years ago.

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VII. Further Discussion

A number of hedge fund strategies designed with the assumption that fat-tail risks are negligible worked well for years. In 2008, however, such strategies finally revealed their vulnerability to fat-tail risk and subsequently failed. The experience of such managers begs the question: Is there any way to guard against fat-tail risk?

At a recent tail risk panel discussion that we attended, a risk manager at a well-regarded hedge fund related hedging against tail risks to avoiding being run over by a bus in two parts:

- First, can you see the bus coming?
- Second, can you get out of the way in time?

We would suggest one additional, but critical step in between: Even if you saw the bus, would you be able to recognize it for what it is? Often we are fully aware of the figurative "bus" from miles away, but very rarely is anyone able to recognize the implications correctly. In such case, misreading of data can be as lethal as not reading the data at all.

At any given time there are many "buses" lurking on the road. One of the most prominent (and perhaps a prevailing theme of 2010) is the issue of sovereign debt defaults in Europe, Japan, or even the United States. To guard against such risks, investors can buy swaps on debt to protect against sovereign credit downgrades, or short the currency in the forex markets. Risk-loving investors and managers may attempt to generate excess returns from bets related to these tail risk events by exploiting pricing inefficiencies. More conservative investors, who are unsure of how things will play out, may simply wish to avoid a possible mess altogether, opting to de-risk by going to the safest instrument available to them.

Yet it is a futile effort to extrapolate how the entire course of events will play out in a tail event. Models used by risk managers use historical data, but as anyone who has dabbled in investments can recite, *past performance is not indicative of future results*. Investors should never assume that the next fat-tail event will play out exactly as the one that came before it.

While 2010 did not see any fat-tail market movements as we defined it for this study, the past year has by no means been a stroll in the park. Market volatility and mounting uncertainty have persuaded many managers to hold positions in gold.

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Especially cautious managers have even attempted to hedge against a possible run on the fractional gold reserve system or government expropriation by moving to offshore deposits of physical gold. This heightened awareness of fat-tail risks, as demonstrated by the desire to hedge against them, is one positive outcome of 2008. Yet is it enough?

The hit-by-a-bus metaphor is an example of the dangers that lie in "known unknowns". But what about the most frightening fat-tail events of all – the so-called "unknown unknowns"? By its very definition, Nassem Taleb's Black Swan theory urged that there are some things that are impossible to predict or understand. The best policy for investors is to simply be cognizant of the existence of a myriad of risks and take measures to mitigate where appropriate, while at the same time not subjecting themselves to the torture of overthinking the matter.

This research piece is an update to *Study of Fat-tail Risk*, originally published in November 2008.

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Eiichiro Kuwana: President/Founding Principal
Eiichiro Kuwana is President and a Founding Principal of Cook Pine Capital. Mr. Kuwana oversees the asset allocation and manager selection processes and has responsibility for investor relations at Cook Pine Capital. Mr. Kuwana brings to Cook Pine Capital 22 years of experience in the financial industry. Prior to starting Cook Pine Capital, Mr. Kuwana spent 12 years at Goldman, Sachs & Co., where he was a Managing Director. Throughout his career at Goldman Sachs, Mr. Kuwana worked closely with wealthy families around the globe, assisted them in investing their personal assets in both the public and private markets, and helped ensure prudent asset allocation, risk management, and wealth preservation. Moreover, Mr. Kuwana held various senior level management positions within the Investment Management and Equities divisions at Goldman Sachs in both New York and Asia. In addition, Mr. Kuwana worked at Merrill Lynch in its Money Markets Origination group based out of New York. Mr. Kuwana received an AB, magna cum laude, and an MBA from Harvard University. Mr. Kuwana serves as a trustee on the board of The Nature Conservancy, Hawai'i.

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FAMILY OFFICE ASSOCIATION

About Family Office Association

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The Family Office Association was started by the entreaty and with the guidance of a handful of single-family offices in Greenwich, Connecticut, who wished to have a regular and safe place to meet others with single family offices and share ideas. True to that spirit, FOA is the trusted and respected source that family offices and families of wealth can turn to for peer networking, expert resources, and fresh perspectives on how to maintain vigorous multi-generational wealth. FOA is the advocate of the concept of establishing and sustaining a single family office devoted to the:

- Preservation of family wealth
- The fostering of Stewardship in the next generation, and
- The expansion of family philanthropic Legacy

FOA endeavors to find the best experts and notables in the family office industry to educate the membership at our Spring, Summer and Fall Summits; monthly breakfast roundtables, and member led peer-to-peer sessions. FOA has hosted such legends at our roundtables and summits as John Paulson, Mike Milken, Bill Ackman, David Einhorn, Izzy Englander, Nassim Taleb, Daniel Loeb, Paul Singer, Richard Perry and Marc Lasry.

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