Abnormal Distributions Produce Irrational Models

Kenneth Potts

March 9, 2017

Abstract

An understanding of financial market returns is critical whether one is planning to hedge risks or or design trading systems intended to profit from market movements. In financial modeling, assumptions are often made in order to obtain a functioning and useful model. When modeling portfolio or asset risk, models such as Value at Risk, or VAR, often make assumptions about an underlying return distribution, then aim to calculate the probability of a large loss of a specified size. Such losses are typically due to events deemed very unlikely given the assumed distribution. The illustrious Black-Scholes option pricing model assumes that asset prices follow an infinitesimal log-normal random walk. Additionally, Harry Markowitz's famed mean variance theory, which describes how to optimally construct a portfolio of assets, assumes that market returns are independent and normally distributed between periods.

There have been many large scale financial events which triggered wild moves in markets that would suggest that market returns are non-normal. Some of these events include the crash on Black Monday in 1987, the breaking of the peg on the Pound Sterling in 1992, the Russian default crisis and the fall of LTCM–Long Term Capital Management, a hedge fund overseen by two Nobel laureates–in 1998, the bursting of the technology bubble in 2000-2001, the bursting of the real estate and debt bubbles in 2007-2008, the flash crash of 2010, the break of the peg on the Swiss Franc in 2015, the Brexit vote in 2016, and the British Pound flash crash of 2016. These such events are illustrations of how unpredictable and wild financial markets can be.

This study aims to analyze returns from the equity and currency markets from the beginning of the 1990s to the end of 2016, which encompasses many of these events. Although present, this study extends beyond these extreme events to analyze returns across various time frames, looking at individual assets and also the equity market as a whole. Through the use of statistical goodness of fit tests and quantile-quantile analysis, the study shows that currency and equity market returns are leptokurtic, or fat tailed. This characteristic persists across all time frames for negative returns. A substitution of the normal distribution for the Laplace distribution can yield a more accurate model of market returns, especially at smaller, or finer, time frames. A T-distribution with 4-5 degrees of freedom is also a potential representative distribution. Autocorrelation is examined as a possible explanation of leptokurtic market behavior, however, autocorrelation is not uniformly present in equity and currency markets.

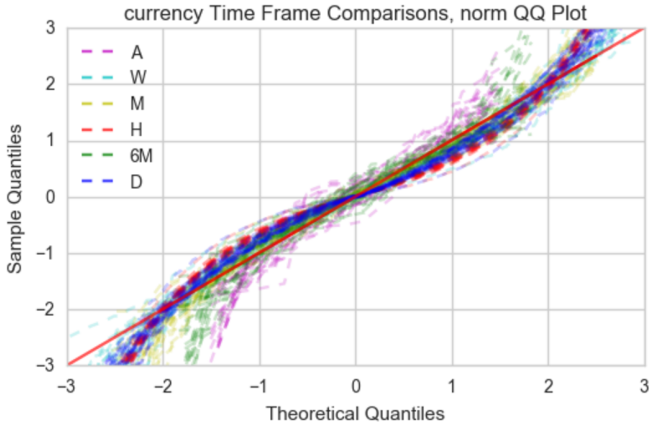

Figure 1: Quantile-Quantile Plot of Currency Market Returns

This project was designed to be an educating exercise in data science and statistics using time series analysis tools in Python. It has opened the doors to another study of the influences of survivorship bias in financial research. A repetition of this study with a survivorship bias free data set may reveal how influential such a bias can be in the analysis of financial risk. The remaining portion of the study is being redirected to investigate when survivorship bias is likely to occur, and how much of an effect it has on studies of this nature.

References

[1] Jushan Bai and Serena Ng. Tests for skewness, kurtosis, and normality for time series data. *Journal of Business and Economic Statistics*, 23(1), 2005.

[2] Aswath Damodaran. Value at risk. http://pages.stern.nyu.edu/ adamodar/pdfiles/papers/VAR.pdf, April 2017. URL http://pages.stern.nyu.edu/~adamodar/pdfiles/papers/VAR.pdf.

[3] David P. Doane and Lori E. Seward. Measuring skewness: A forgotten statistic? *Journal of Statistics Education*, 19(2), 2011.

[4] Carlos M. Jarque and Anil K. Bera. Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economic Letters*, 6(3):255–259, 1980.

[5] Malcolm H. D. Kemp. *Extreme events: robust portfolio construction in the presence of fat tails.* Wiley, 2011.

[6] Kazuhisa Matsuda. Introduction to black-scholes model. http://www.maxmatsuda.com/Papers/Intro/IntroDecember 2004. URL http://www.maxmatsuda.com/Papers/Intro/Intro%20to%20BS%20Matsuda.pdf.

[7] NIST/SEMATECH. *Handbook of Statistical Methods: Measures of Skewness and Kurtosis.* NIST, 2012.

[8] Evgenia Nitishinskaya, Maxwell Margenot, and Delaney Granizo-Mackenzie. Statistical moments. Quantopian Lecure Series, 2015. URL https://www.quantopian.com/lectures#Statistical-Moments.

[9] William J. Reed. *The Laplace Distribution and its Relatives.* 2004.

[10] Abdullah Z. Sheikh and Hongtao Qiao. *Non-normality of Market Returns Non-normality of Market Returns.* J.P. Morgan Asset Management, 2009.