MEAN REVERSION OF VOLATILITY AROUND EXTREME STOCK RETURNS: EVIDENCE FROM U.S. STOCK INDEXES

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ABSTRACT

This paper examines mean reversion processes in volatility structure of stock markets after extremely high or low stock returns. The stock market volatility is reflected in three aspects, overall volatility, volatility momentum, and volatility concentration, and they are measured by three basic statistical measures, variance/standard deviation, skewness, and kurtosis, respectively. The results of this study illustrate remarkable reversions in volatility momentum, concentration, and level between periods of pre- and post-extremely high stock returns. Evidence of this study also supports some strong volatility reversions after extremely negative stock returns. The findings are helpful to investing professionals and financial policy makers to expand their understanding of different aspects of volatility structure and their change cycles. The knowledge may enhance effectiveness of portfolio managers in risk management after busts of stock price bubbles.

JEL: G10

KEYWORDS: Volatility Reversion, Volatility Momentum, Volatility Concentration, Volatility Level

INTRODUCTION

Since Francis Galton first reported the regression to the mean phenomenon in his experiments on the size of the seeds of successive generations of sweet peas in the late 1860s (Bulmer, 2003) and human characteristics with a natural tendency of "regression towards mediocrity" (Galton, 1886), many studies have discovered the mean reversion in stock returns, for example, Fama and French (1988a, 1988b), Poterba and Summers (1988), Kim, Nelson, and Startz (1991), and Cochran and DeFina (1994). However, there is not much empirical evidence on the mean reversion in volatility of stock returns, or stock market volatility. A difficulty in analyzing volatility reversion is the structure of volatility. Unlike stock returns which are simply measured with percentage changes in stock prices, the stock market volatility is reflected in three different aspects, overall volatility, volatility momentum, and volatility concentration. The volatility structure makes analyses of volatility reversion more complex, compared with examines of mean reversions in stock returns.

The volatility structure can be measured by three basic statistical concepts. The most popular volatility measure for stock returns is standard deviation which calculates the dispersion of a data set from its mean. In the calculation, both positive and negative differences from the mean are counted and never offset each other. The standard deviation simply represents the weighted average of all differences (excess positive and negative stock returns) and therefore, quantifies the overall volatility of stock returns. A high value of standard deviation depicts a high level of variability in the stock market.

However, volatility in stock returns shows both biased (positive or negative) persistence and momentum shifting, from positive to negative, or vice versa. If a data set has a normal distribution, all observations are distributed in a symmetric manner, the momentum is unbiased. In fact, stock returns may not follow the normal distribution and volatility momentum may be skewed to the left or right of the mean. Therefore, skewness, a measure of the negative and positive skew, estimates volatility momentum. In a bullish market stock returns are positively skewed; while negatively skewed stock returns indicate a bearish market.

Although skewness can tell the direction of skew in volatility momentum, it fails to separate the impact of extreme stock returns on the shape or concentration of volatility. The concentration of volatility around the mean is revealed in the fatness of the tails of a distribution which is measured by kurtosis. In a normal distribution, kurtosis has a value of 3. If there is a flatter peak around the mean with thin tails, compared with a normal distribution, the distribution is known as platykurtic. It may suggest large variations in stock returns, that is, the returns are less concentrated around the mean, but further deviated from the mean. In contrast, a leptokurtic distribution has a higher peak than normal distribution around the mean with thick tails. It suggests that returns tend to concentrate around the mean.

Findings of previous studies indicate that the three volatility measures can play important roles in explaining variation in stock returns and their volatility which reveal the reversion to mean pattern. The phenomenon of mean reversion is particularly striking after stock prices experience resilient appreciations or dire corrections (He, 2009). However, no studies in the literature examine the long-term reversions of the volatility structure represented by the three volatility measures over explicit periods of time after extreme stock returns. In order to make one step further in this line of research, this paper is to explore reversions of various volatility measures in major stock markets.

The reminder of the paper is organized in the following manner. Section two briefly discusses the relevant literature. Section three describes analytical methods and the data used in the study. Section four presents and analyzes empirical results, and the last section summarizes findings.

LITERATURE REVIEW

Although many financial analyses today are still based on a simple assumption of normal distribution of stock returns, some economists challenged the validity of the assumption many decades ago. For example, Hicks (1946) found that the asymmetric distribution of stock returns could significantly affect investors' decisions and Samuelson (1970) suggested that investors should use the first three moments (mean, variance, and skewness) to build their portfolios when stock return distribution was skewed. Mandelbrot (1963, 1967) discovered persistent excess kurtosis, the fourth moment, in stock returns. The persistent excess kurtosis is consistent with volatility clustering phenomenon in which large (positive or negative) fluctuations in stock returns tend to be followed by large (positive or negative) return changes. The lack of appropriate evaluation of this fat-tail risk is considered as one of "the biggest problems" by Greenspan (1997). In fact, variance, skewness, and kurtosis reflect different aspects of volatility of stock returns.

Findings of previous studies indicate that the above three volatility measures play important roles in determining stock prices and have different impacts on investing decisions. It is verified by many studies that investors have a preference for positive skewness (for instance, Kraus and Litzenberger (1976), Kane (1982), Brockett and Kahane (1992), and Peiro (1999)). In estimating their three moment CAPM, Kraus and Litzenberger (1983) discover a negative relationship between systematic skewness and stock returns. Campbell and Siddique (2000) further report that the systematic skewness may carry a 3.60% risk premium. In Fang and Lai' (1997) CAPM all three volatility measures are included. Their results not only confirm previous findings on the relationship between skewness and stock returns and investors' preference toward skewness, but also indicate that investors dislike variance and kurtosis and demand higher returns for taking higher systematic variance and kurtosis.

Given the relevance and importance of the volatility structure, the volatility change pattern is definitely an interesting issue to investors. Many researchers reported findings on change patterns in stock markets.

Among them the reversion to mean in stock markets is well documented. Despite a rich literature on the mean reversion in stock markets, some studies suggest that long-run changes in stock markets may simply reflect extreme stock return reversals rather than mean reversion. Nonetheless, in his recent study of processes of mean aversion and reversion in the S&P 500 Stock Index over a period of 123 years, He (2009) provides additional evidence that long-run stock returns tend to go back to the historical average level after stock markets experience extreme fluctuations. Results of previous studies indicate that the reversion to mean exists not only in stock returns but also in stock volatility. For example, Randolph (1991) uses a mean reversion model to predict stock market volatility. His model suggests that current expected volatility is a function of how much past volatility differed from the long-run level and how quickly the volatility reverts to this long-run level. Therefore, the model can be used to estimate the parameters of the stochastic volatility process and predict volatility. Similar models are used to forecast stock index futures price volatility (Randolph and Najand, 1991).

Further, some studies use the GARCH model to test the mean reversion of conditional variance. For instance, Dueker (1997) relates Markov switching in GARCH process with mean-reverting volatility in the stock market. Theodossiou et al (1997) extend their study of mean reversion to international stock markets. They report empirical evidence from the U.S., U. K. and Japan stock markets that conditional variance in their GARCH model reverts back to the long-run equilibrium level after it departs from the level. More recently, Bali and Demirtas (2008) conducted a comprehensive study of continuous time GARCH modeling with the thin-tailed normal and the fat-tailed Student's-t and generalized error distributions. Their results indicate that their models can capture the mean reversion process in stochastic volatility. Their evidence from the S&P 500 Index Futures suggests that the conditional variance, log-variance, and standard deviation of futures returns regress towards the long-run average level over time.

Although conditional variance and different measures of variance are found mean reverting in previous papers, there are few studies explicitly devoted to explore potential change patterns in the volatility structure which includes volatility level, momentum, and concentration. The potential contribution of this study is to examine reversion processes of the three aspects of volatility structure in stock markets over explicit periods of time after extreme stock returns.

METHODOLAGY AND DATA

Extreme fluctuations in stock prices can cause dramatic changes not only in stock returns, but also in volatility momentum, volatility concentration, and overall volatility in stock markets. After those extreme changes stock returns are to revert to their historical average. Since stock returns are very dynamic in nature, it is expected that the process of reversion to mean includes both stock returns as well as three aspects of volatility structure. That is, after extreme stock price changes all three volatility measures may respectively revert to their previous levels after certain time intervals, such as six or 12 months. In order to test volatility reversions from one period after (F1) to one period before (B1) extreme stock returns, it is important to examine and compare normality of stock returns in the pre-sample (B1) and post-sample (F1), since changes in skewness (measure of volatility momentum) and kurtosis (measure of volatility concentration) not only reflect the normality of stock returns but also affect the normality. If skewness in F1 is not significantly different from skewness in B1, a reversion of volatility momentum is verified. Similarly, a comparison of kurtosis between F1 and B1 can detect a potential reversion of volatility concentration.

Normally, a statistical test for normality takes skewness and kurtosis simultaneously into consideration. However, only separate tests for skewness and kurtosis can measure reversions of volatility momentum and concentration independently. This study uses the Jarque-Bera test (JB) as the basic method to test the normality of a series of stock returns. The test statistic is originally computed as $\mathrm{JB} = \frac{N}{6}\left(S^2 + \frac{(K-3)^2}{4}\right)$, where S represents skewness and K is kurtosis. The Jarque-Bera statistic is distributed as χ^2 with two degrees of freedom. In order to exam how significantly skewness and kurtosis affect normality of a series of stock returns, respectively, this study divides the Jarque-Bera statistic into following two components,

$$\text{JB for Skewness} = (\frac{N}{6} \times S^2) \qquad (1)$$

$$\text{JB for Kurtosis} = [\frac{N}{6} \times (\frac{(K-3)^2}{4})] \qquad (2)$$

Both (1) and (2) have the χ^2 distribution and one degree of freedom and can test the significance of effects of skewness and kurtosis on normality, respectively. These two statistics can also test the significance of effects of changes in skewness and kurtosis on normality over the period of B1 through F1, if S gauges difference of skewness between F1 and B1 and K represents variation in kurtosis between F1 and B1. The insignificant statistics indicate inconsequential changes in skewness or kurtosis between F1 and B1, that is, reversions of volatility momentum or volatility concentration from F1, post-sample, to B1, pre-sample.

Finally, the F-test in analysis of variance (ANOVA) is used to examine equality of variance for stock returns between F1 and B1. An insignificant test statistic indicates a reversion of overall volatility from F1 to B1. The equality of average stock returns between the two periods is verified by the t-test.

The monthly Nasdaq Composite Index and the S&P 500 Stock Index are used in this study. The earliest data for the Nasdaq index is February, 1971. Therefore, the sample period in this study extends from that date to August, 2010. Two series of 463 annual rolling returns are created based on the two stock indexes. The comparison period of B1 and F1takes about 12 months, therefore, the effective sample period for extreme stock returns covers February, 1972 to August 2009. The number of observation is 439. The top 10% of returns (44) is defined as the extremely high returns and the bottom 10% the extremely low returns. Similarly, 45 semiannual rolling returns are determined as extremely high or low returns, respectively.

EMPIRICAL RESULTS

The average of 44 extremely high S&P annual rolling returns (High) is 34.17%, compared with 4.87% one year ago (B1) and 9.67% one year later (F1); the standard deviation of the 44 extremely high returns is 6.20% vs. 17.72% (B1) and 14.61% (F1); the skewness is 1.49 vs. -0.38 and -0.30; and the kurtosis is 4.64 vs. 1.81 and 1.93 (Table 1). Statistics of equality tests reported in Panel A indicate that the mean, skewness, kurtosis of High are significantly, at the one percent level, higher than that of B1 and F1, as expected; while variance of High is significantly lower than that of B1 and F1, because High is a nonrandom or biased sample of extremely high annual rolling returns which contain small differences.

Results in Panel B provide strong evidence for reversions of mean, variance, skewness, and kurtosis from F1 to B1, that is, all differences are statistically insignificant. The results illustrate a long-term change pattern in the stock market. One year after extremely upbeat stock returns, they tend to fall to the level two years ago (B1). This change (reversion to mean) incorporates reduced stock returns, increased overall volatility, negatively biased momentum, and a much lower level of concentration around mean. The negative skewness and lower level of kurtosis indicate a correction in the stock market after it created extreme stock returns. The increased standard deviation simply tells us the correction is a volatile process. More importantly, the changes in the process of reversion to mean have implied boundaries, the levels one year before extremely high stock returns, for stock returns as well as all three aspects of volatility structure, respectively. Although it is not possible to predict exact timing and levels stock returns and volatility structure revert to after extremely positive returns, the information of long-term change pattern in the stock market is important to investment and risk management decisions.

The lower part of Table 1 contains results for extremely low S&P annual rolling returns (Low). In contrast to B1 and F1, Low, not surprisingly, has a significantly lower mean and standard deviation; and a similar kurtosis. However, its skewness of -0.79 is significantly different from 0.35 for B1 and comparable to -0.41 for F1 (Panel C). Results of equality tests in Panel D suggest significant different mean, variance, and skewness for B1 and F1, therefore, there are no reversions take place. Although JB for Kurtosis (0.20) is insignificant, the result does not imply the reversion of kurtosis from F1 to B1, because there is no meaningful change in kurtosis, it basically remains the same from B1 → Low→ F1.

Table 1. Descriptive Statistics and Equality Tests for S&P Extreme Annual Rolling Returns and Their Backward and forward Returns (February 1972 – August 2010)

Descriptive Statistics for 44 Extremely High Returns and Their Backward and Forward Returns				
Variables	**Mean**	**St. Deviation**	**Skewness**	**Kurtosis**
B1	0.0487	0.1772	-0.3826	1.8084
High	0.3417	0.0620	1.4889	4.6401
F1	0.0967	0.1461	-0.3035	1.9347
Panel A: Statistics of Equality Tests for Rolling Volatilities				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. High	-10.354	8.1633	25.684	12.894
	(0.000)	(0.000)	(0.000)	(0.000)
High vs. F1	10.237	5.5510	23.652	11.695
	(0.000)	(0.000)	(0.000)	(0.001)
Panel B: Statistics of Equality Tests for Volatility Reversions				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. F1	1.9263	1.4706	0.0458	0.0292
	(0.169)	(0.210)	(0.831)	(0.864)
Descriptive Statistics for 44 Extremely Low Returns and Their Backward and Forward Returns				
Variables	**Mean**	**St. Deviation**	**Skewness**	**Kurtosis**
B1	-0.0168	0.1458	0.3542	2.4384
Low	-0.2546	0.0801	-0.7871	2.2075
F1	0.1279	0.2243	-0.4075	2.1112
Panel C: Statistics of Equality Tests for Rolling Volatilities				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. Low	9.4831	3.3129	9.5519	0.0977
	(0.000)	(0.000)	(0.002)	(0.755)
Low vs. F1	-10.654	7.8435	1.0564	0.0170
	(0.000)	(0.000)	(0.304)	(0.896)
Panel D: Statistics of Equality Tests for Volatility Reversions				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. F1	4	2.3676	4.2552	0.1963
	(0.001)	(0.001)	(0.039)	(0.658)

High is extremely high annual rolling returns. Low is extremely low annual rolling returns. Statistics of Equality Tests reported in Panels A, B, C, and D include t-value for mean, F-statistic for variance, JB for Skewness =(N/6 x S^2)(Equation 1) and JB for Kurtosis =[N/6 x $(K-3)^2/4$] (Equation 2). B1 is annual returns one year before extreme returns. F1 is annual returns one year after extreme returns. P-values are in parentheses.

Extremely high S&P semiannual rolling returns show more supportive evidence of volatility reversions, compared to the extremely high annual returns. Reversions of mean, variance, skewness, and kurtosis are detected from two 6-month periods after High (F2) back to two 6-month periods before High (B2) by statistics of equality tests reported in Panel B of Table 2. Reversion of volatility momentum measured with skewness is even stronger and swifter. Over a 6-month period, skewness changes from -0.64 for B1 to 1.30 for High. After another 6-month period, the positive momentum changes to -0.43 for F1. The result of JB for Skewness indicates that skewness for F1 and B1 is statistically indifferent (Table 2) and the reversion of volatility momentum takes six months after the extremely high returns. Reversion of kurtosis, the measure of concentration of volatility, reveals the same pattern, that is, from F1 to B1 and from F2 to B2. Reversion of overall volatility (variance or standard deviation) is a longer market process, only from F2 to B2.

Table 2. Descriptive Statistics and Equality Tests for 45 S&P Extremely High SemiAnnual Rolling Returns and Their Backward and Forward Returns (August 1971 – August 2010)

Descriptive Statistics				
Variables	**Mean**	**St. Deviation**	**Skewness**	**Kurtosis**
B2	0.0278	0.1248	0.0870	2.3058
B1	-0.0052	0.1313	-0.6398	3.6182
High	0.2249	0.0464	1.2950	4.4261
F1	0.0503	0.0843	-0.4265	3.7751
F2	0.0425	0.1032	0.1155	1.9600
Panel A: Statistics of Equality Tests for Rolling Volatilities				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B2 vs. B1	1.2238	1.1072	3.9620	3.2293
	(0.224)	(0.737)	(0.047)	(0.072)
B1 vs. High	11.089	8.0050	28.076	1.2238
	(0.000)	(0.000)	(0.000)	(0.269)
High vs. F1	12.172	3.3000	22.227	0.7946
	(0.000)	(0.000)	(0.000)	(0.373)
F1 vs. F2	0.3967	1.4982	2.2032	6.1773
	(0.693)	(0.184)	(0.138)	(0.013)
Panel B: Statistics of Equality Tests for Volatility Reversions				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. F1	-2.3897	2.4257	0.3412	0.0462
	(0.019)	(0.004)	(0.560)	(0.830)
B1 vs. F2	-1.9163	1.6191	4.2784	5.1554
	(0.059)	(0.114)	(0.039)	(0.023)
B2 vs. F1	-1.0040	2.1910	1.9779	4.0477
	(0.318)	(0.011)	(0.160)	(0.044)
B2 vs. F2	-0.6073	1.4624	0.0061	0.2242
	(0.545)	(0.211)	(0.938)	(0.636)

High is extremely high semiannual rolling returns. Statistics of Equality Tests reported in Panels A and B include t-value for mean, F-statistic for variance, JB for Skewness =(N/6 x S^2) (Equation 1) and JB for Kurtosis =[N/6 x $(K-3)^2/4$] (Equation 2). P-values are in parentheses.
B1 is semiannual returns six months before extremely high returns. B2 is semiannual returns 12 months before extremely high returns.
F1 is semiannual returns six months after extremely high returns. F2 is semiannual returns 12 months after extremely high returns.

Table 3 reports results for 45 extremely low semiannual rolling returns. Unlike the annual data, the semiannual data demonstrates a rapid and clear reversion of volatility momentum from F1 to B1, as suggested by the insignificant statistic of JB for Skewness, 0.116, in Panel B of Table 3. The remarkable reversion of volatility concentration is also found from F2 to B1 (or B2).

Compared with the large-cap stock dominated S&P index, the 44 extremely high annual rolling returns of the Nasdaq Composite Index have a much higher mean (56.22% vs. 34.17%) and overall volatility (15.17% vs. 6.20%). The results are consistent with the consensus that small-cap stocks usually generate higher returns and greater instability. Nonetheless, there is no evidence that Nasdaq High has greater volatility momentum and concentration than S&P High. In fact, both skewness and kurtosis for Nasdaq High (Table 4) are slightly lower than that for S&P High. Panel B of Table 4 provides strong evidence for reversion to mean phenomenon for stock returns, price volatility, momentum, and volatility concentration from F1 to B1. The results are almost identical to S&P High.

In the worst market conditions, the Nasdaq index reveals much deeper losses than the S&P index. The average of 44 extremely low Nasdaq annual rolling returns is -35.92% (Table 4), in contrast to -25.46% for the S&P index (Table 1). Further dissimilarity lies in the robust evidence supporting reversions of stock returns, price volatility, and volatility concentration for Nasdaq Low, although, evidence for the reversion of momentum is absent (Panel D of Table 4).

Statistical evidence from 45 extremely high Nasdaq semiannual rolling returns confirms reversions of stock returns, momentum, and volatility concentration from F1 to B1 and from F2 to B2 (Table 5).

Table 3. Descriptive Statistics and Equality Tests for 45 S&P Extremely Low SemiAnnual Rolling Returns and Their Backward and Forward Returns (August 1971 – August 2010)

Descriptive Statistics				
Variables	**Mean**	**St. Deviation**	**Skewness**	**Kurtosis**
B2	0.0013	0.0968	0.8069	3.1305
B1	-0.0226	0.1042	0.2386	3.1132
Low	-0.1795	0.0831	-1.0738	3.0459
F1	0.0298	0.1610	0.3628	2.5508
F2	0.0671	0.1436	-0.8629	4.0086
Panel A: Statistics of Equality Tests for Rolling Volatilities				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B2 vs. B1	1.1281	1.1580	2.4220	0.0006
	(0.262)	(0.629)	(0.120)	(0.981)
B1 vs. Low	7.8981	1.5722	12.919	0.0085
	(0.000)	(0.137)	(0.000)	(0.927)
Low vs. F1	-7.7483	3.7555	15.480	0.4597
	(0.000)	(0.000)	(0.000)	(0.498)
F1 vs. F2	-1.1588	1.2564	11.267	3.9848
	(0.250)	(0.452)	(0.001)	(0.046)
Panel B: Statistics of Equality Tests for Volatility Reversions				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. F1	-1.8326	2.3887	0.1157	0.5931
	(0.070)	(0.005)	(0.734)	(0.441)
B1 vs. F2	-3.3897	1.9012	9.0997	1.5033
	(0.001)	(0.036)	(0.003)	(0.220)
B2 vs. F1	-1.0167	2.7662	1.4790	0.6303
	(0.312)	(0.001)	(0.224)	(0.427)
B2 vs. F2	-2.5462	2.2017	20.911	1.4456
	(0.013)	(0.010)	(0.000)	(0.229)

Low is extremely low semiannual rolling returns. Statistics of Equality Tests reported in Panels A and B include t-value for mean, F-statistic for variance, JB for Skewness =(N/6 x S^2) (Equation 1) and JB for Kurtosis =[N/6 x $(K-3)^2/4$] (Equation 2). B1 is semiannual returns six months before extremely low returns. B2 is semiannual returns 12 months before extremely low returns. F1 is semiannual returns six months after extremely low returns.F2 is semiannual returns 12 months after extremely low returns. P-values are in parentheses.

Table 4. Descriptive Statistics and Equality Tests for Nasdaq Extreme Annual Rolling Returns and Their Backward and forward Returns (February 1972 – August 2010)

Descriptive Statistics for 44 Extremely High Returns and Their Backward and Forward Returns				
Variables	**Mean**	**St. Deviation**	**Skewness**	**Kurtosis**
B1	0.0286	0.2429	0.3189	1.8543
High	0.5622	0.1517	1.1516	3.5039
F1	-0.0234	0.2968	0.2112	2.7763
Panel A: Statistics of Equality Tests for Rolling Volatilities				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. High	-12.361	2.5650	5.0845	4.9886
	(0.000)	(0.003)	(0.024)	(0.026)
High vs. F1	11.655	3.8290	6.4843	0.9703
	(0.000)	(0.000)	(0.011)	(0325)
Panel B: Statistics of Equality Tests for Volatility Reversions				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. F1	0.8992	1.4928	0.0850	1.5586
	(0.371)	(0.193)	(0.771)	(0.212)
Descriptive Statistics for 44 Extremely Low Returns and Their Backward and Forward Returns				
Variables	**Mean**	**St. Deviation**	**Skewness**	**Kurtosis**
B1	0.0771	0.4202	0.6189	2.3958
Low	-0.3592	0.0918	-0.8763	2.9167
F1	0.1118	0.3299	-0.0941	1.4503
Panel C: Statistics of Equality Tests for Rolling Volatilities				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. Low	6.7282	20.962	16.393	0.4974
	(0.000)	(0.000)	(0.000)	(0.481)
Low vs. F1	-9.1222	12.925	4.4863	3.9423
	(0.000)	(0.000)	(0.034)	(0.047)
Panel D: Statistics of Equality Tests for Volatility Reversions				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. F1	-0.4312	1.6218	3.7279	1.6391
	(0.667)	(0.117)	(0.054)	(0.200)

High is extremely high annual rolling returns. Low is extremely low annual rolling returns. Statistics of Equality Tests reported in Panels A, B, C, and D include t-value for mean, F-statistic for variance, JB for Skewness =(N/6 x S^2) (Equation 1) and JB for Kurtosis =[N/6 x $(K-3)^2/4$] (Equation 2). B1 is annual returns one year before extreme returns. F1 is annual returns one year after extreme returns.P-values are in parentheses.

The results suggest reversions of stock returns, volatility momentum, and volatility concentration in the Nasdaq market from six-month and 12-month after- to before-High, respectively. However, dissimilar to the annual returns, the semiannual returns do not display the reversion of the overall volatility. The standard deviation remains the same (about 17%) during the before-High period (from B1 to B2) and stable right after extremely high returns (from High to F1).

The significant changes only occur in the following two periods, from B2 to High and from F1 to F2 (Table 5). These asymmetric changes in standard deviation may be an important factor which prevents the reversion of the overall volatility.

Table 5. Descriptive Statistics and Equality Tests for 45 Nasdaq Extremely High SemiAnnual Rolling Returns and Their Backward and Forward Returns (August 1971 – August 2010)

Descriptive Statistics				
Variables	**Mean**	**St. Deviation**	**Skewness**	**Kurtosis**
B2	0.0146	0.1737	0.7702	4.6144
B1	0.0038	0.1745	-0.0129	3.1447
High	0.3720	0.1005	1.6346	5.5988
F1	0.0520	0.1217	0.3503	3.1174
F2	-0.0017	0.2362	0.7564	4.6392
Panel A: Statistics of Equality Tests for Rolling Volatilities				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B2 vs. B1	0.2956	1.0099	4.5997	4.0499
	(0.768)	(0.974)	(0.032)	(0.044)
B1 vs. High	-12.263	3.0161	20.356	11.293
	(0.000)	(0.000)	(0.000)	(0.001)
High vs. F1	13.601	1.4653	12.370	11.545
	(0.000)	(0.209)	(0.000)	(0.001)
F1 vs. F2	1.3561	3.7698	1.2369	4.3422
	(0.179)	(0.000)	(0.266)	(0.037)
Panel B: Statistics of Equality Tests for Volatility Reversions				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. F1	-1.5211	2.0583	0.9894	0.0014
	(0.132)	(0.019)	(0.320)	(0.970)
B1 vs. F2	0.1249	1.8315	4.4387	4.1878
	(0.901)	(0.048)	(0.035)	(0.041)
B2 vs. F1	-1.1830	2.0381	1.3225	4.2018
	(0.240)	(0.020)	(0.250)	(0.040)
B2 vs. F2	0.3734	1.8497	0.0014	0.0012
	(0.710)	(0. 044)	(0. 970)	(0. 973)

High is extremely high semiannual rolling returns.
B1 is semiannual returns six months before extremely high returns.
B2 is semiannual returns 12 months before extremely high returns.
F1 is semiannual returns six months after extremely high returns.
F2 is semiannual returns 12 months after extremely high returns.
Statistics of Equality Tests reported in Panels A and B include t-value for mean, F-statistic for variance, JB for Skewness =(N/6 x S^2*) (Equation 1) and JB for Kurtosis =[N/6 x* $(K-3)^2/4$*] (Equation 2).*
P-values are in parentheses.

In contrast to the extremely high Nasdaq semiannual rolling returns, the extremely low Nasdaq semiannual rolling returns reveal a pattern of the overall volatility reversion for any periods after Low to any periods before Low (Table 6). The mean reversion is detected from both F1 and F2 to B2. There is no evidence found to support the reversions of volatility momentum and concentration.

Table 6. Descriptive Statistics and Equality Tests for 45 Nasdaq Extremely Low SemiAnnual Rolling Returns and Their Backward and Forward Returns (August 1971 – August 2010)

Descriptive Statistics				
Variables	**Mean**	**St. Deviation**	**Skewness**	**Kurtosis**
B2	0.0487	0.2343	1.1394	3.7707
B1	-0.0445	0.1806	1.1666	8.7219
Low	-0.2645	0.0783	-0.7553	2.8913
F1	0.0590	0.2249	-0.0681	2.3815
F2	0.0499	0.1903	-0.2660	2.1505
Panel A: Statistics of Equality Tests for Rolling Volatilities				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B2 vs. B1	2.1126	1.6822	0.0056	45.964
	(0.038)	(0.088)	(0.941)	(0.000)
B1 vs. Low	7.4963	5.3252	27.702	63.743
	(0.000)	(0.000)	(0.000)	(0.000)
Low vs. F1	-9.1147	8.2527	3.5418	0.4872
	(0.000)	(0.000)	(0.060)	(0.485)
F1 vs. F2	0.2061	1.3574	0.2937	0.1001
	(0.837)	(0.315)	(0.588)	(0.752)
Panel B: Statistics of Equality Tests for Volatility Reversions				
Variables	**Mean**	**Variance**	**Skewness**	**Kurtosis**
B1 vs. F1	-2.4078	1.5498	11.434	75.375
	(0.018)	(0.150)	(0.000)	(0.000)
B1 vs. F2	-2.3961	1.1417	15.392	80.969
	(0.019)	(0.662)	(0.000)	(0.000)
B2 vs. F1	-0.2141	1.0854	10.935	3.6183
	(0.831)	(0.787)	(0.001)	(0.057)
B2 vs. F2	-0.0278	1.4734	14.813	4.9222
	(0.978)	(0.203)	(0.000)	(0.027)

Low is extremely low semiannual rolling returns. Statistics of Equality Tests reported in Panels A and B include t-value for mean, F-statistic for variance, JB for Skewness =$(N/6 \times S^2)$ (Equation 1) and JB for Kurtosis =$[N/6 \times (K-3)^2/4]$ (Equation 2). B1 is semiannual returns six months before extremely low returns. B2 is semiannual returns 12 months before extremely low returns. F1 is semiannual returns six months after extremely low returns. F2 is semiannual returns 12 months after extremely low returns. P-values are in parentheses.

CONCLUDING CONMMENTS

The purpose of this study is to explore mean reversion processes in volatility structure of stock market after extremely high or low stock returns. Three basic descriptive statistics of variance/standard deviation, skewness, and kurtosis are used to measure overall volatility level, volatility momentum, and volatility concentration, respectively. Two broad stock indexes, the monthly S&P 500 Stock Index and Nasdaq Composite Index, serve as stock market proxies. The analysis of reversion of volatility structure provide compelling evidence that in general, six or twelve months after extremely high returns, stock markets display reversions of the volatility level, momentum, and concentration to their pre-high levels. The detected volatility reversions indicate a symmetric pattern in volatility changes in a cycle of pre-high → high→ post-high, that is, volatility levels, momentums, and concentrations in the pre- and post-high periods are similar. This is consistent with the mean reversion phenomenon. Information revealed in the reversion of volatility is definitely relevant and important in predicting future stock market movements.

However, results of this study, overall, reveal a more complicated picture for volatility reversions after extremely low returns. For instance, S&P extremely low semiannual rolling returns demonstrate reversions of volatility momentum and concentration. On the other hand, the reversion of overall volatility level is detected only in the Nasdaq market. In addition, the volatility concentration one year after extremely low stock returns in the Nasdaq market tends to revert to the level one year before extremely low returns.

In general, the results of this paper illustrate important change patterns in volatility momentum, concentration, and level between periods of pre- and post-extreme stock returns. The findings provide investing professionals and financial policy makers with additional insights into the behavior of the stock market, especially the different aspects of volatility structure and their change cycles. The knowledge may enhance effectiveness of portfolio managers in risk management after busts of stock price bubbles.

As an early attempt to examine the mean reversion of volatility structure, this study focuses on U.S. stock markets only. However, many previous studies find that world major stock markets are closely connected to each other and there are significant price and volatility spillovers among different stock markets in the world. Therefore, it is fruitful for future studies on this topic to expand to international stock markets.

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