# RETURN VOLATILITY MOVEMENTS IN SPOT AND FUTURES MARKETS: EVIDENCE FROM INTRADAY BEHAVIOR OF THE S&P 500 INDEX

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## ABSTRACT

After the Debt Ceiling Bill was passed on August 2, 2011, the S&P 500 index returns volatility increased significantly until the end of 2011. This research investigates the return volatility movements in S&P 500 spot index and index futures markets, the lead/lag relationship between two markets, and the effect of volatility on the trading costs using year 2011 intraday data. The analyses of intraday data show the following results during the higher volatility period (8/3/2011–12/30/2011): First, the difference of return variances between index futures and spot index is even greater than that during the lower volatility period. Second, the index futures market leads the spot index market and the interaction between both markets becomes stronger. Third, both index futures and spot index exhibit clearer U-shape intraday pattern of return volatilities. Finally, the trading costs, measured by the bid-ask spreads, are significantly larger.



**JEL:** G13, G14

**KEYWORDS:** Intraday Return Volatility, S&P 500 Index, Spot and Futures Markets, Bid-Ask Spreads


## INTRODUCTION

In 2011, after many days' political gridlock, the Debt Ceiling Bill was passed by Congress on August 2, 2011 to avoid the default of debt. However, on August 5, 2011, Standard and Poor (S&P) downgraded the U.S. government's credit rating from AAA to AA+. On August 9, 2011, Federal Reserve decided to keep the federal funds rate close to zero percent at least through mid-2013. After the passage of the Debt Ceiling Bill, negative and positive information flowed swiftly and the stock market seesawed, experiencing several downs and ups. The pattern of volatile stock market seems to continue until the end of 2011. To initially verify this pattern, the daily closing S&P 500 indices data from the beginning of January 2011 to the end of June 2012, collected from Yahoo Finance website, are analyzed. The daily S&P 500 index returns are calculated by taking the first difference of natural logarithm of daily closing S&P 500 indices. The graph and summary statistics of S&P 500 Index Daily Returns are shown on Figure 1 and Table 1a, presented on the section of empirical results.

Based on Figure 1 and Table 1a, the daily returns appear to become more volatile from August 3, 2011 to the end of year 2011. During 8/3/2011-12/30/2011, the maximum daily return is 0.0463, the minimum daily return is –0.0690, and the variance of returns is 0.0004. The F-Test comparing two-sample for variance is performed and the result is presented on Table 1b, shown on the section of empirical results. The F-test comparing 1/3/2011–8/2/2011 and 8/3/2011–12/30/2011 two sample periods, indicates that the return volatility for 8/3/2011–12/30/2011 is significantly greater than that for 1/3/2011–8/2/2011. The F-Test comparing 8/3/2011–12/30/20111 and 1/3/2012–6/29/2012 two sample periods, also indicates that the return volatility for 8/3/2011–12/30/2011 is significantly greater than that for 1/3/2012–6/29/2012. Therefore, the stock market did exhibit the greater volatility during the last five months of 2011.

The significantly greater volatility of index returns during the 5-month period of 8/3/2011–12/30/2011 provides us a good opportunity to re-investigate the volatility related issues through a microstructure perspective. The aforementioned finding is only based on daily data. Is the result still robust if high-frequency intraday index data are used and minute-to-minute returns are calculated? The index futures market is related to the spot index market. Is the difference of return volatilities between index futures and spot index even greater during the higher volatility period? Which market leads/lags the other market? Does index futures or spot index market lead the other or neither one leads the other? During the regular trading hours, what are the intraday patterns of return volatilities for spot index and index futures? Are the patterns different when the return volatility increases? In addition, the trading costs, measured by bid-ask spreads, are also an important issue to be examined. How does the volatility affect the trading costs? Do the trading costs of stock market increase during the higher volatility period?

Although previous studies had examined most of issues listed above, these issues were not addressed altogether, but partially in separate research papers using older and different time period data. In this research, more recent year (2011) data are used to investigate all of the above issues to see whether there are additional findings to complement the literature. The remaining sections of this paper are arranged as follows. The literature review is done on the next section. After that, data and methodology are discussed and then the empirical results are presented. Finally, the conclusion is summarized.

## LITERATURE REVIEW

Past studies compare volatilities of spot index and index futures and discuss intraday volatility patterns of stocks and index futures in 1980s and 1990s. Using intraday S&P 500 index data for the fourth quarters of 1984, 1985, and 1986, Kawaller et al. (1990) find that the volatility of index futures is greater than the volatility of spot index and volatilities of both index futures and spot index increased with the trading volume of index futures. They also find that volatility increased for both index futures and spot index in absolute terms from 1984 to 1986 and index volatility was the highest during the first 30 minutes of trading each day. However, they find no systematic pattern of the lead/lag relationship between index futures and spot index markets using Granger causality tests.

Wood and McInish (1985) use transaction data for six months from September 1971 to February 1972 and for the year 1982 to investigate intraday returns behavior and several trading characteristics for NYSE stocks. They find that stock returns and standard deviations of returns are unusual high during the beginning of trading day and the end of trading day as well. Ekman (1992) uses S&P 500 index futures intraday data from January 1983 to November 1988 to examine whether the intraday patterns exist for returns, volatility of returns, number of trades, and autocorrelation of returns. He uses the absolute value of return as the proxy of volatility and finds that the intraday S&P 500 index futures volatility follows the U-Shape pattern except that the volatility decreases in the last 30 minutes of trading.

As to the dynamics and price discovery for spot index and index futures, Kawaller et al. (1993) indicate that the dynamic relationship between S&P 500 index futures and spot index markets strengthens when the volatility of index futures prices increase. Chu et al. (1999) examine the price discovery roles of the S&P 500 spot index, index futures, and Depositary Receipts (SPDRs) and conclude that index futures contribute the most significant price discovery; SPDRs the second, spot index the least. Hasbrouck (2003) suggests that the price discovery is mainly dominated by index futures for S&P 500 index and Nasdaq-100 index and the contributions of exchange-traded-funds (ETFs) to the price discovery are smaller. So and Tse (2004) explore the price discovery for Hang Seng index, index futures, and tracker fund markets of Hong Kong and find that index futures provide the most price discovery information, spot index the second, but no contribution to the process of price discovery is made by the tracker fund. Tse et al. (2006) investigate the price discovery dynamics of the Dow Jones Industrial Average (DJIA) index, regular index futures, E-mini futures, and the DIAMOND ETF and they point out that the price discovery is mostly contributed by E-mini futures.

For the literature about the bid-ask spreads, Copeland and Galai (1983) model the bid-ask spread valuation by pointing out two types of traders in the market, liquidity traders and informed traders.

Liquidity traders trade to get immediacy and informed traders trade based on their special information. The market maker is expected to gain from liquidity traders due to the cost for immediacy paid by them. However, the market maker is only expected to lose to informed traders because they posses more information. Although setting a wider bid-ask spread can reduce the potential loss to informed traders, it also decreases the expected gain from liquidity traders. Vice Versa; a narrower spread can increase the expected gain from liquidity traders, but it also increases the potential loss to informed traders. They indicate that the market maker aims to set the optimal bid-ask spread to maximize profits by weighing the trade-off relationship. They also show that price level and return variances positively affect the bid-ask spreads but trading volume negatively affects the spreads.

McInish and Wood (1992) use NYSE stocks' quote data during the first half of year 1989 to examine the intraday pattern of percentage bid-ask spreads and test the hypotheses for the determinants of the spreads. They find that the intraday pattern of spreads exhibit a reverse J-shaped pattern; spreads are highest at the beginning of the trading day and then gradually decline but move up before the end of trading day. They demonstrate that spreads are directly related to the level of risk but inversely related to the trading activity. Besides, they find that trades with unusual large size, which reflects information content are associated with wider spreads. Also, the spreads are likely to decrease with greater competition from regional exchanges but the direction of causality is not sure. Wang et al. (1994) utilize the intraday data from September 1987 to May 1988, covering the October 1987 market crash, to explore main factors determining the realized spread and price volatility of S&P 500 index futures. Their results show that the main determinants of the realized spread are the number of market makers, volume per trade, and price risk. They indicate that price volatility is affected by the spread, lagged one-period number of trade, and short-term interest rate volatility.

Regarding the liquidity and volatility of microstructure studies in more recent years, Chung and Kim (2009) investigate the influence of return volatility on the liquidity in different market structures. They find that when the market is more volatile, the NYSE specialist structure provides higher liquidity than the Nasdaq dealer structure. They attribute this phenomenon to a designated NYSE specialist system versus non-designated Nasdaq dealer system; for each NYSE-list stock, a designated specialist maintains a proper level of liquidity but for each Nasdaq-list stock, there is no such a designated dealer. Chelley-Steeley and Park (2011) research the intraday behavior of transaction costs and volatility for the London Stock Exchange listed ETFs and find that the bid-ask spreads and volatility of ETFs are higher at the beginning of a trading day but are not raised at the end of a trading day. Their explanation is that information accumulates when the market is closed and then affects the market at the opening of the next trading day, leading to higher spreads and volatility.

## DATA AND METHODOLOGY

Intraday data for S&P 500 spot index and S&P 500 index futures for the time period January 3, 2011 (the first trading date for 2011) to December 30, 2011 (the last trading date for 2011) are from Tick Data company. Index futures data are used based on the data of most active contract. Based on intraday data, minute-to-minute returns for spot index (index futures) are calculated by taking the first difference of natural logarithm of minute closing S&P 500 indices (prices of index futures). Then, the return variance of spot index (index futures) for each day is calculated by using minute-to-minute returns for spot index (index futures) in each day. For spot index, the stock trading for each day is from 8:30 AM CST to 3:00 PM CST (from 9:30 AM EST to 4:00 PM EST) so there are 390 one-minute spot index returns for each day. If a minute's closing index is missing (empty), it would be filled in with the last value. Very few (only four) missing values occur in 2011 spot index data. On 11/25/2011, the market closed at 12 PM CST (1 PM EST) so there are only 210 one-minute returns on that day. The regular futures floor trading is from 8:30 AM CST to 3:15 PM CST (from 9:30 AM EST to 4:15 PM EST). To match spot index and index futures on the same time interval for each day, the futures trading price data after 3:00 PM CST for each day are ignored. So, there are also 390 one-minute index futures returns for each day. For index futures, there may be no quote appearing in a minute or several minutes in a day. If this situation occurs, the most recent index futures quote is used as the closing futures price for that minute.

According to the preliminary result discussed in introduction section, year 2011 (1/3/2011–12/30/2011) is divided into two sample periods: 1/3/2011–8/2/2011 (lower volatility period) and 8/3/2011–12/30/2011 (higher volatility period). There are 147 trading days from 01/03/2011 to 08/02/2011 and 105 trading days from 08/03/2011 to 12/30/2011. For each trading day, the return variance for spot index and the return variance for index futures are calculated and formed a pair in order to compare. Therefore, there are 147 pairs for the time period of 01/03/2011 to 08/02/2011 and 105 pairs for the time period of 08/03/2011 to 12/30/2011. To test whether daily index futures return variances are significantly different from daily spot index return variances, the Paired T-Test is used and its equation is as follow.

$$t = \frac{\bar{d}}{S_d / \sqrt{n}}, \tag{1}$$

where $\bar{d}$ is the mean of the differences between the paired observations; $S_d$ is the standard deviation of the differences between the paired observations; $n$ is the number of paired observations. To test whether there is lead/lag relationship between spot index and index futures markets, the two-equation model is used as follow.

$$\begin{aligned} v_{s,t} &= \alpha_0 + \sum_{j=1}^{Q_1} \alpha_j v_{s,t-j} + \sum_{j=1}^{Q_2} \beta_j v_{f,t-j} + \varepsilon_t, \\ v_{f,t} &= \kappa_0 + \sum_{j=1}^{Q_1} \kappa_j v_{f,t-j} + \sum_{j=1}^{Q_2} \omega_j v_{s,t-j} + \mu_t, \end{aligned} \tag{2}$$

where $v_{s,t}$ is the return variance for spot index at day t; $v_{f,t}$ is the return variance for index futures at day t; $Q_1$ is the number of lag for the dependent (endogenous) variables; $Q_2$ is the number of lag for the independent (exogenous) variables. The two-equation model is estimated using seemingly unrelated regression (SUR), assuming error terms are heteroskedastic and contemporaneously correlated across equations. Geweke (1978) argues that the number of lags on the dependent variables in each equation ($Q_1$) should be kept generous to minimize the chance of serially correlated errors, while the number of lags on the independent variables ($Q_2$) should be set lower to retain power in the hypothesis tests. Therefore, $Q_1 = 10, 15$ and $Q_2= 3, 5, 10$ are used in this study.

Based on equation (2), return volatility of index futures is said to Granger-cause return volatility of spot index if return volatility of spot index can be better estimated by its past return volatility and the past return volatility of index futures rather than only its past return volatility. Similarly, return volatility of spot index is said to Granger-cause return volatility of index futures if return volatility of index futures can be better estimated by its past return volatility and the past return volatility of spot index rather than only its past return volatility. To test the Granger-Causality, Wald Test F-statistic is used to test the following two joint hypotheses.

Hypothesis 1 ($H_1$): $\beta_1 = \beta_2 = \cdots = \beta_{Q2} = 0$

Hypothesis 2 ($H_2$): $\omega_1 = \omega_2 = \cdots = \omega_{Q2} = 0$

To find the intraday pattern of return volatility for index futures and spot index, the minute-by-minute return variances for index futures and spot index need to be calculated. There are 6.5 trading hours (390 trading minutes) in a trading day. For each trading minute (the first to the 390$^{th}$ minute), its return variance is computed across days within the entire year 2011 and each sample period as well.

To measure the bid-ask spreads, tick-by-tick intraday quote data with bid and ask prices are required. Since S&P 500 index does not have bid and ask prices, SPDR (S&P 500 ETF; ticker (SPY)), which tracks the performance of S&P 500 index, is used as the proxy to compute the spreads. SPY tick-by-tick intraday quote data (with time-stamp given to milliseconds) for each trading day during year 2011 (1/3/2011 to 12/30/2011) are from Tick Data company. For each trading day, the quotes during regular trading hours (from 9:30 AM EST to 4:00 PM EST) are used. There are initially 1.8 billion quotes for SPY during the regular trading hours of all trading days in year 2011 (1/3/2011 to 12/30/2011). The quoted spread and percentage quoted spread are calculated as follows.

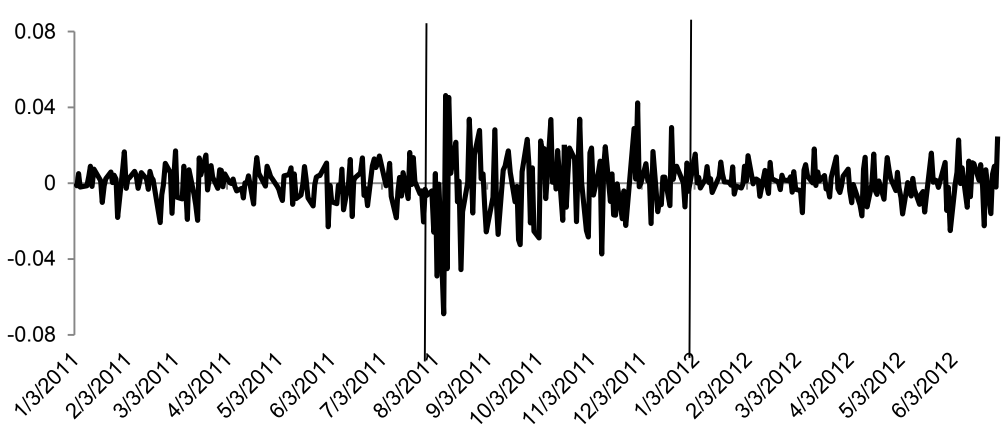
$$Quoted\ Spread = A_t - B_t\ , \tag{3}$$

$$Percentage\ Quoted\ Spread = \left(A_t - B_t\right)/M_t\ , \tag{4}$$

where $B_t$ and $A_t$ represent the national best bid and offer (NBBO), respectively, for SPY at time t; $M_t = (A_t + B_t)/2$, is the quoted midpoint for SPY at time t. The quote with zero bid price or zero ask price or bid price > ask price is not considered for the NBBO. The way used to derive the NBBO follows Tick Data Technical Paper (2009) and Hasbrouck (2010). Besides, the NBBOs with locked or crossed quotes are excluded. The average quoted spread and average percentage quoted spread computed for each day during year 2011 (1/3/2011 to 12/30/2011) are time-weighted average quoted spread and percentage quoted spread. The time-weighted average quoted spread and percentage quoted spread are calculated for each day during year 2011 and then are classified into two sample periods. F-test is performed to see whether variances of spreads for both sample periods are significantly different. If F-test does (does not) show the significant difference, T-test for two-sample assuming unequal (equal) variances is conducted to see whether spreads for two sample periods are statistically significantly different.

## EMPIRICAL RESULTS

Figure 1: S&P 500 Index Daily Returns




*This figure shows the time series plots for the daily S&P 500 index returns, calculated by taking the first difference of natural logarithm of daily closing S&P 500 indices, from 1/3/2011 to 6/29/2012.*

Table 1a: Summary Statistics of S&P 500 Index Daily Returns

| Sample Period | 1/3/2011 – 8/2/2011 | 8/3/2011 – 12/30/2011 | 1/3/2012 – 6/29/2012 |
|---|---|---|---|
| Mean of Returns | $-9.664\times10^{-5}$ | $2.692\times10^{-5}$ | $6.389\times10^{-4}$ |
| Median of Returns | $7.089\times10^{-4}$ | $1.948\times10^{-3}$ | $4.862\times10^{-4}$ |
| Maximum Return | $1.707\times10^{-2}$ | $4.632\times10^{-2}$ | $2.461\times10^{-2}$ |
| Minimum Return | $-2.589\times10^{-2}$ | $-6.896\times10^{-2}$ | $-2.495\times10^{-2}$ |
| Variance of Returns | $7.287\times10^{-5}$ | $4.195\times10^{-4}$ | $7.200\times10^{-5}$ |
| Standard Deviation of Returns | $8.536\times10^{-3}$ | $2.048\times10^{-2}$ | $8.485\times10^{-3}$ |
| Number of Returns | 146 | 105 | 125 |

*Note: There are 147 trading days during 1/3/2011-8/2/2011. Since the daily closing S&P 500 index data are collected starting 1/3/2011, the daily return of 1/3/2011 cannot be computed. So, the daily return is computed starting 1/4/2011 and there are 146 daily returns during 1/3/2011-8/2/2011.*

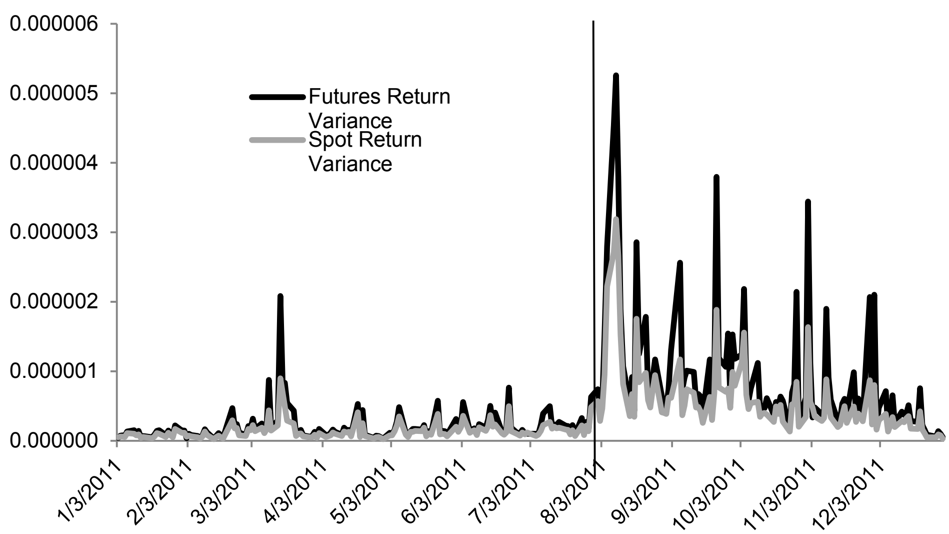
Table 1b: F-Test for Comparing Return Variances for Two Sample Periods

| Sample Period | 8/3/2011 – 12/30/2011 | 1/3/2011 – 8/2/2011 |
|---|---|---|
| Variance Of Returns | $4.195\times10^{-4}$ | $7.287\times10^{-5}$ |
| F-Statistics (P-Value) | $5.758^{***}$ (< 0.01) | |
| **Sample Period** | **8/3/2011 – 12/30/2011** | **1/3/2012 – 6/29/2012** |
| Variance Of Returns | $4.195\times10^{-4}$ | $7.200\times10^{-5}$ |
| F-Statistics (P-Value) | $5.827^{***}$ (< 0.01) | |

*This table shows the F-Test for comparing two variances: F-Statistics = $S_1^2/S_2^2$, where $S_1^2$ and $S_2^2$ are respective variances of return for sample period 1 (8/3/2011–12/30/2011) and period 2 (1/3/2011–8/2/2011 or 1/3/2012–6/29/2012). *** indicates significance at 1% level.*

Figure 2 shows daily return variances for S&P 500 spot index and index futures for year 2011. There are three findings on Figure 2. First, daily return variances for both spot index and index futures increase after 8/2/2011. Second, index futures return variances appear to be higher than spot index return variances for year 2011.

Figure 2: Daily Return Variances for S&P 500 Spot Index and Index Futures




*This figure shows daily return variances for S&P 500 spot index and index futures for year 2011 (1/3/2011-12/30/2011). Based on intraday data, minute-to-minute returns for spot index (index futures) are calculated by taking the first difference of natural logarithm of minute closing S&P 500 indices (prices of index futures). Then, the return variance for each day is calculated by using minute-to-minute returns in each day.*

Third, the gap of return variances between index futures and spot index during the higher volatility period (8/3/2011–12/30/2011) appears to be much greater than that during the lower volatility period (1/3/2011–8/2/2011). Table 2 displays the Paired T-Test (Paired Two-Sample for Means) for mean of differences between paired daily index futures return variances and daily spot index return variances during two sample periods and year 2011, which confirms that the volatility for index futures is statistically significantly greater than that for spot index for both sample periods and year 2011. Not displayed on Table 2, the T-test comparing two sample periods' differences of return variances between index futures and spot index (assuming unequal variances) shows T-statistics (p value) of 6.4789 (< 0.01), indicating difference of variances during the higher volatility period (8/3/2011-12/30/2011) is significantly greater than that during the lower volatility period (1/3/2011–8/2/2011).

Table 2: Paired T-Test (Paired Two-Sample for Means) for Daily Minute-to-Minute Return Variance

| **1/3/2011 – 8/2/2011** | **Index Futures** | **Spot Index** |
|---|---|---|
| Mean of Variances | $2.070\times10^{-7}$ | $1.458\times10^{-7}$ |
| Mean of Differences between Paired Observations | $6.120\times10^{-8}$ | |
| Standard Deviation of Differences of Paired Observations | $1.144\times10^{-7}$ | |
| T-Statistics (p value) | $6.489^{***}$ (< 0.01) | |
| **8/3/2011 – 12/30/2011** | **index futures** | **Spot Index** |
| Mean of Variances | $9.459\times10^{-7}$ | $6.022\times10^{-7}$ |
| Mean of Differences between Paired Observations | $3.437\times10^{-7}$ | |
| Standard Deviation of Differences of Paired Observations | $4.363\times10^{-7}$ | |
| T-Statistics (p value) | $8.074^{***}$ (< 0.01) | |
| **1/3/2011 – 12/30/2011** | **index futures** | **Spot Index** |
| Mean of Variances | $5.149\times10^{-7}$ | $3.360\times10^{-7}$ |
| Mean of Differences between Paired Observations | $1.789\times10^{-7}$ | |
| Standard Deviation of Differences of Paired Observations | $3.255\times10^{-7}$ | |
| T-Statistics (p value) | $8.726^{***}$ (<0.01) | |

*This table shows the Paired T-Test (Paired Two-Sample for Means) for mean of differences between paired daily index futures return variances and daily spot index return variances during two sample periods (1/3/2011–8/2/2011 and 8/3/2011–12/30/2011) and year 2011 (1/3/2011–12/30/2011). There are 147 paired observations for 01/03/2011–08/02/2011, 105 paired observations for 08/03/2011–12/30/2011, and 252 paired observations for 01/03/2011–12/30/2011. T-Statistics are computed using equation (1). *** indicates significance at 1% level.*

Table 3 shows the results of testing the volatility of lead/lag relationship between index futures and spot index market. For $H_1$ ($v_{f,t} \rightarrow v_{s,t}$) Period I (1/3/2011–8/2/2011), no matter what $Q_1$ and $Q_2$ are, none of F-statistics is significant. This indicates the null hypothesis, $\beta_1 = \beta_2 = \cdots = \beta_{Q2} = 0$, cannot be rejected. Therefore, there is no lead/lag relationship between both markets. The return volatility of index futures does not Granger-cause return volatility of spot index. The return volatility of spot index can be estimated by only its past return volatility. For $H_1$ ($v_{f,t} \rightarrow v_{s,t}$) Period II (8/3/2011–12/30/2011), no matter what $Q_1$ and $Q_2$ are, all of F-statistics are significant at 5% level. Two F-statistics are even significant at 1% level. This indicates the null hypothesis, $\beta_1 = \beta_2 = \cdots = \beta_{Q2} = 0$, is rejected. Therefore, the volatility of index futures leads the volatility of spot index. The return volatility of index futures is said to Granger-cause return volatility of spot index. The volatility of spot index can be better estimated by its past return volatility and the past return volatility of index futures.

For $H_2$ ($v_{s,t} \rightarrow v_{f,t}$) Period I (1/3/2011–8/2/2011), no matter what $Q_1$ and $Q_2$ are, none of F-statistics is significant. This indicates the null hypothesis, $\omega_1 = \omega_2 = \cdots = \omega_{Q2} = 0$, cannot be rejected. Therefore, there is no lead/lag relationship between both markets. The return volatility of spot index does not Granger-cause return volatility of index futures. The return volatility of index futures can be estimated by only its past return volatility. For $H_2$ ($v_{s,t} \rightarrow v_{f,t}$) Period II (8/3/2011–12/30/2011), half of F-statistics (three out of six) are significant at 5% level. The test results can reject the null hypothesis, $\omega_1 = \omega_2 = \cdots = \omega_{Q2} = 0$, for partial combinations of $Q_1$ and $Q_2$ but not for all, using 5% significance level as the standard,. Based on Table 3 and the above discussion, the results differ with the degree of volatility. During the low volatility period (1/3/2013–8/2/2013), no lead/lag relationship between two markets is found. During the high volatility period (8/3/2011–12/30/2011), the volatility of index futures leads the volatility of spot index and the interaction between index futures and spot index markets becomes significant and stronger. Intuitively, when the volatility increases, information flow in market is faster so that futures market leads spot market and both markets interact closer with each other.

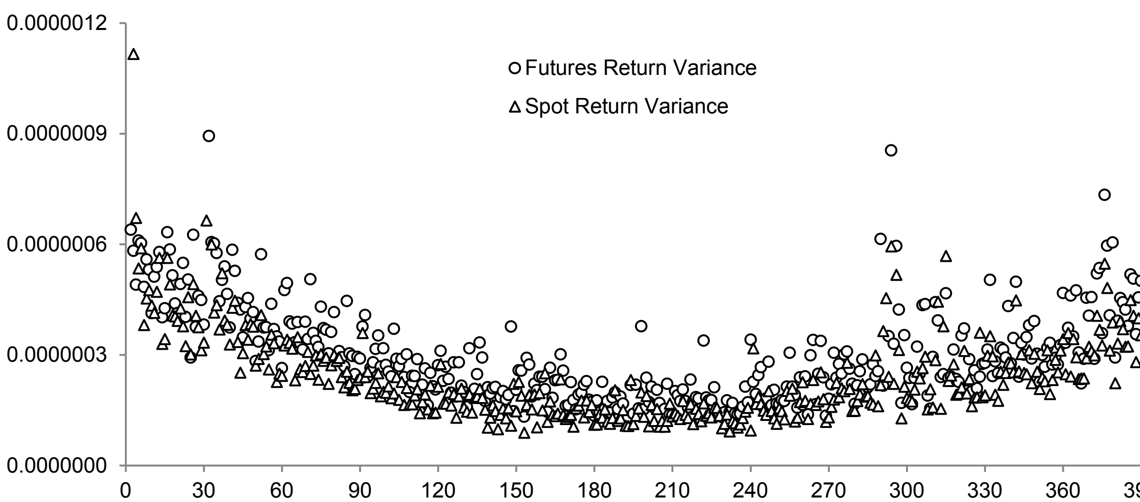
Table 3: Testing the Volatility of Lead/Lag Relationship between Index Futures and Spot Index

| $Q_1$ | $Q_2$ | Sample Period | $H_1$ ($v_{f,t} \rightarrow v_{s,t}$): SUR F-Statistics (p value) | $H_2$ ($v_{s,t} \rightarrow v_{f,t}$): SUR F-Statistics (p value) |
|---|---|---|---|---|
| 10 | 3 | Period I | 0.29 (0.8352) | 1.26 (0.2873) |
| | | Period II | 4.22 (0.0066)*** | 2.85 (0.0390)** |
| 10 | 5 | Period I | 0.83 (0.5306) | 1.34 (0.2469) |
| | | Period II | 2.72 (0.0218)** | 2.30 (0.0479)** |
| 10 | 10 | Period I | 1.00 (0.4472) | 1.28 (0.2425) |
| | | Period II | 2.13 (0.0258)** | 1.68 (0.0906)* |
| 15 | 3 | Period I | 0.28 (0.8411) | 1.07 (0.3635) |
| | | Period II | 4.67 (0.0038)*** | 3.05 (0.0307)** |
| 15 | 5 | Period I | 0.85 (0.5166) | 1.27 (0.2777) |
| | | Period II | 2.81 (0.0190)** | 2.28 (0.0504)* |
| 15 | 10 | Period I | 0.96 (0.4766) | 1.20 (0.2927) |
| | | Period II | 2.02 (0.0364)** | 1.75 (0.0767)* |

*This table shows results of testing the volatility of lead/lag relationship between index futures and spot index market. $v_{s,t}$ is the return variance for spot index at day t. $v_{f,t}$ is the return variance for index futures at day t. $Q_1$ is the number of lag for the dependent (endogenous) variables. $Q_2$ is the number of lag for the independent (exogenous) variables. The two-equation model (equation (2), shown in data and methodology section) is estimated using seemingly unrelated regression (SUR), assuming error terms are heteroskedastic and contemporaneously correlated across equations. Period I is 1/3/2011–8/2/2011. Period II is 8/3/2011–12/30/2011. ***, **, * indicate significance at 1%, 5%, and 10% levels, respectively.*

Figure 3 displays the intraday patterns of return variance for index futures and spot index for year 2011 (1/3/2011–12/30/2011). The vertical axis is the return variance and the horizontal axis is the trading minutes of a day. There are 6.5 trading hours (390 trading minutes) in a day. According to Figure 3, the return variance is highest at the first 30 minutes (8:30 AM to 9:00 AM CST), and then it goes down and reaches the lowest around the 180$^{th}$ (11:30 AM CST) to 240$^{th}$ minute (12:30 PM CST), and then it goes up until the end of trading time. Both index futures and spot index markets show the U-shape pattern of return volatility. In addition, the volatility of index futures is higher than the volatility of spot index. Basically, the pattern on Figure 3 is consistent to Wood and McInish (1985) that the volatility is higher during the beginning of trading day and the end of trading day.

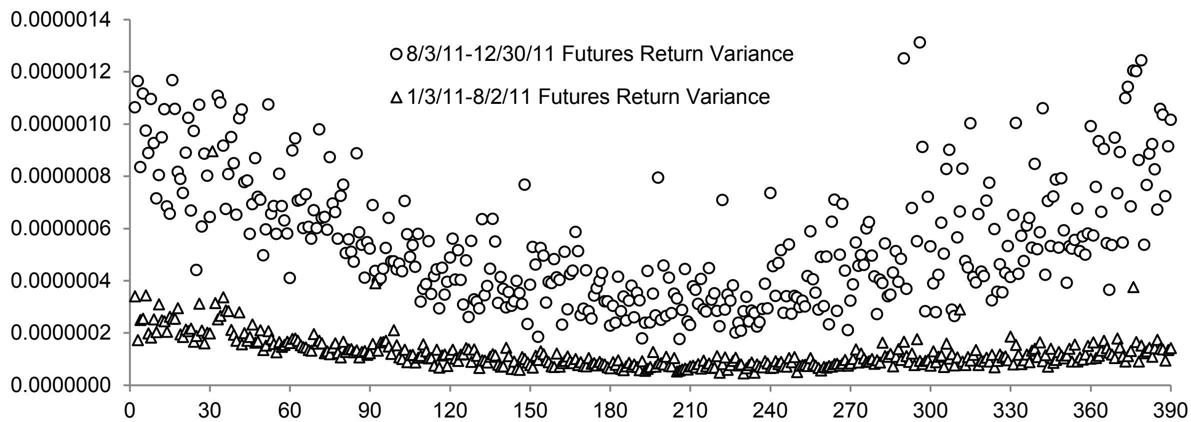
Figure 3: Return Variances of Index Futures and Spot Index across Days (1/3/2011–12/30/2011)




*This figure displays the intraday patterns of return variance for index futures and spot index for year 2011 (1/3/2011–12/30/2011). The vertical axis is the return variance and the horizontal axis is the trading minutes of a day. There are 6.5 trading hours (390 trading minutes) in a day. Note: the plots for the first minute's future return variance (0.00008023), the first minute's spot return variance (0.00003182), and the second minute's spot return variance (0.00000407) are not shown in the figure because their values are much greater than other plots' values and far beyond the range of the vertical axis.*

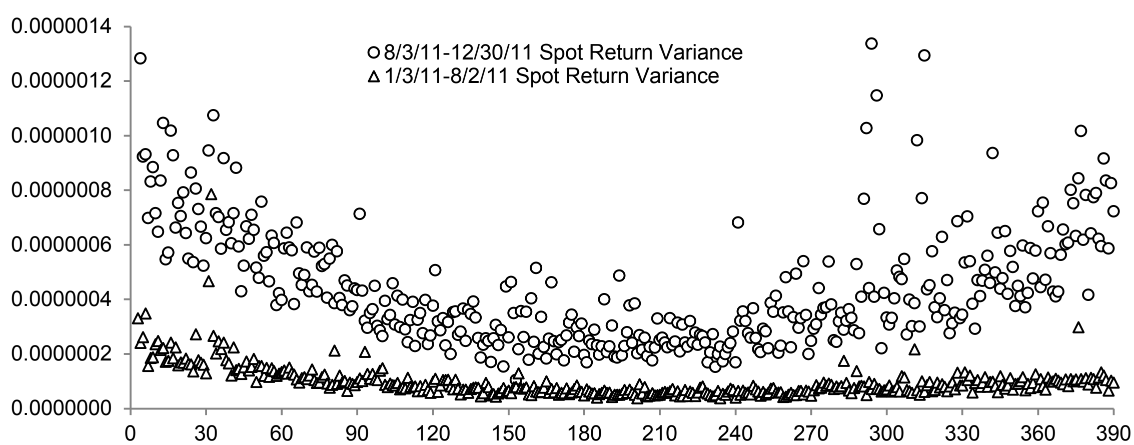
Figure 4a breaks down the intraday pattern of return variances of index futures into two sample periods for year 2011. During the higher volatility period (8/3/2011–12/30/2011), the return variances of index futures appear to be much higher for all 390 minutes of a trading day than the lower volatility period (1/3/2011–8/2/2011) and the U-shape pattern is more obvious. Figure 4b, which divides the intraday pattern of return variances of spot index into two sample periods for year 2011, shows the similar pattern. During the higher volatility period (8/3/2011–12/30/2011), the return variances of spot index are much higher for all 390 minutes of a trading day than the lower volatility period (1/3/2011–8/2/2011) and the U-shape pattern is even clear. The clearer U-shape intraday pattern for both markets during the higher volatility period implies that the difference of return variances between two sample periods is larger at the beginning and end of a trading day than the rest of time of a trading day. Both markets' investors face even greater risk when trading at the beginning and end of a day during the higher volatility period.

Figure 4a: Return Variances of Index Futures across Days (1/3/2011–8/2/2011 and 8/3/2011–12/30/2011)




*This figure breaks down the intraday patterns of return variances of index futures into two sample periods (8/3/2011–12/30/2011 and 1/3/2011–8/2/2011) for year 2011. The vertical axis is the return variance and the horizontal axis is the trading minutes of a day. There are 6.5 trading hours (390 trading minutes) in a day. Note: the plots for the 1st, 31st, 32nd, 292nd, and 294th minute's futures return variances during the sample period of 8/3/2011–12/30/2011 are 0.00014696, 0.00000403, 0.00000171, 0.00000509, and 0.00000196, respectively. The plot for the 1st minute's future return variance during the sample period of 1/3/2011–8/2/2011 is 0.00003291. These 6 plots are not shown in the figure because their values are much greater than other plots' values and far beyond the range of the vertical axis.*

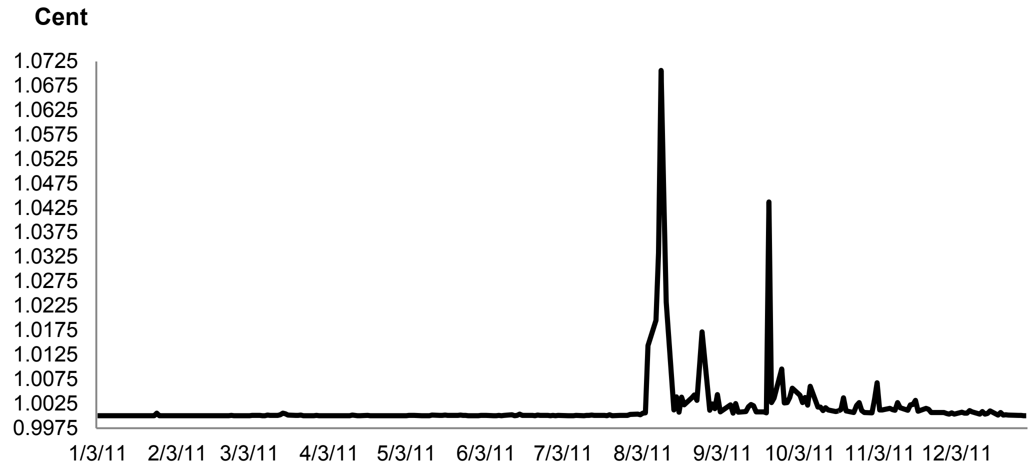
Figure 4b: Return Variances of Spot Index across Days (1/3/2011–8/2/2011 and 8/3/2011–12/30/2011)




*This figure breaks down the intraday patterns of return variances of spot index into two sample periods (8/3/2011–12/30/2011 and 1/3/2011–8/2/2011) for year 2011. The vertical axis is the return variance and the horizontal axis is the trading minutes of a day. There are 6.5 trading hours (390 trading minutes) in a day. Note: the plots for the 1st, 2nd, 3rd, and 32nd minute's spot return variances during the sample period of 8/3/2011–12/30/2011 are 0.00005237, 0.00000764, 0.00000222, and 0.00000410, respectively. The plots for the 1st and 2nd minute's spot return variances during the sample period of 1/3/2011–8/2/2011 are 0.00001728 and 0.00000156, respectively. These 6 plots are not shown in the figure because their values are much greater than other plots' values and far beyond the range of the vertical axis.*

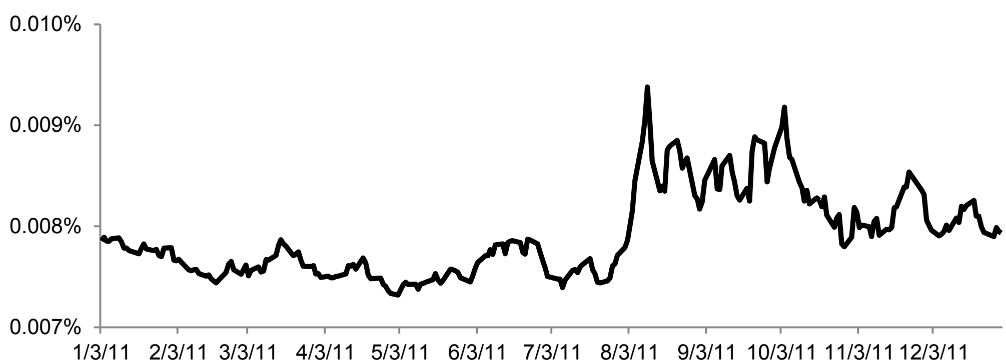
The time-weighted average quoted spread and percentage quoted spread are calculated for each trading day of year 2011 (from 1/3/2011 to 12/30/2011). The time series plots of calculated time-weighted average quoted spreads and percentage quoted spreads are shown on Figure 5a and Figure 5b, respectively. Time-weighted average quoted spread (and percentage quoted spread as well) on 11/25/2011 is regarded as an outlier and is excluded due to its unusual large value. From Figure 5a, the quoted spreads are almost around 1 cent in lower volatility period (1/3/2011–8/2/2011) and they become greater than 1 cent until the end of 2011 in higher volatility period (8/3/2011–12/30/2011). Based on Figure 5b, the percentage quoted spreads are always less than 0.008% in lower volatility period (1/3/2011–8/2/2011) and they are above 0.008% for most of days with even greater than 0.009% on some days in higher volatility period (8/3/2011–12/30/2011). Both figures display that the spreads are larger during the higher volatility period (8/3/2011–12/30/2011).

Figure 5a: Time-Weighted Quoted Spreads from 1/3/2011 to 12/30/2011




*This figure shows the time-weighted quoted spread for each trading day of year 2011 (1/3/2011–12/30/2011). Note: the time-weighted quoted spread on 11/25/2011 is regarded as an outlier and is excluded due to its unusual large value.*

Figure 5b: Time-Weighted Percentage Quoted Spreads from 1/3/2011 to 12/30/2011




*This figure shows the time-weighted percentage quoted spread for each trading day of year 2011 (1/3/2011–12/30/2011). Note: the time-weighted percentage quoted spread on 11/25/2011 is regarded as an outlier and is excluded due to its unusual large value.*

T-test is used to statistically demonstrate whether the spreads are greater in high volatility period. First, F-Test for comparing two-sample period variances of spreads: $F - Statistics = S_1^2 / S_2^2$ , where $S_1^2$ and $S_2^2$ are respective variances of spreads for the higher volatility period (8/3/2011–12/30/2011) and the lower volatility period (1/3/2011–8/2/2011), is performed and the result of F-test proves that two-sample period variances are significantly different. The variances of quoted spreads and the variances of percentage quoted spreads for two sample periods are shown on Table 4. F-statistics for comparing two-sample period variances of quoted spreads and percentage quoted spreads are 12,537.2031 and 5.4822, respectively. Both F-statistics indicate significant difference of variances at 1% level.

Second, T-Test for comparing two sample periods – assuming unequal variances: $T - Statistics = \bar{x}_1 - \bar{x}_2 \Big/ \sqrt{\left(s_1^2/n_1\right) + \left(s_2^2/n_2\right)}$ where $\bar{x}_1, s_1^2, n_1$ are mean of spreads, variance of spreads, and number of trading days, respectively, for the higher volatility period (8/3/2011–12/30/2011) and $\bar{x}_2, s_2^2, n_2$ are mean of spreads, variance of spreads, and number of trading days, respectively, for the lower volatility period (1/3/2011–8/2/2011), is conducted. T-Test results, shown on Table 4, demonstrate that both time-weighted quoted spread and percentage quoted spread in higher volatility period (8/3/2011–12/30/2011) are significantly greater than those in lower volatility period (1/3/2011–8/2/2011) at 1% level.

Table 4: T-Test for Comparing Time-Weighted Spreads for Two Sample Periods

| **Quoted Spread** | | |
|---|---|---|
| **Sample Period** | **8/3/2011 – 12/30/2011** | **1/3/2011 – 8/2/2011** |
| Mean (Cent: ¢) | 1.0043¢ | 1.0001¢ |
| Variance | $1.000\times10^{-8}$ | $7.976\times10^{-13}$ |
| T-Statistics (p-value) | $4.301^{***}$ (< 0.01) | |
| **Percentage Quoted Spread** | | |
| **Sample Period** | **8/3/2011 – 12/30/2011** | **1/3/2011 – 8/2/2011** |
| Mean (%) | 0.0083% | 0.0076% |
| Variance | $1.153\times10^{-11}$ | $2.104\times10^{-12}$ |
| T-Statistics (p-value) | $20.019^{***}$ (< 0.01) | |

*This table shows the T-Test for comparing time-weighted quoted spreads and percentage quoted spreads for two sample periods (8/3/2011–12/30/2011 and 1/3/2011–8/2/2011) – assuming unequal variances. *** indicates significance at 1% level.*

The results are consistent with the literature that the bid-ask spreads are wider when the volatility increases. During the higher volatility period, market information changes faster and information asymmetry risk increases. Although setting the higher spreads may decrease the expected gains from liquidity traders, it reduces the losses to informed traders. The impact of informed trading surpasses the impact of liquidity trading to the market makers when adverse information risk goes up. So, the market makers set the higher spreads to decrease their losses to informed traders during the higher volatility period.

## CONCLUSION

This study re-examines the return volatility movements in S&P 500 spot index and index futures markets, the lead/lag relationship between two markets, and the effect of volatility on the trading costs using year 2011 intraday data. The usage of more recent year data to re-investigate volatility-related issues can complement the literature. The results are summarized as follows. The volatility for index futures is significantly greater than that for spot index in both sample periods of year 2011. During the higher volatility period, the gap of return variances between index futures and spot index is even greater than that during the lower volatility period. During the higher volatility period, the index futures market leads the spot index market and the interaction between both markets becomes stronger but no lead/lag relationship between two markets exists during the lower volatility period. During the higher volatility period, both index futures and spot index exhibit clearer U-shape intraday pattern of return volatilities, which means that both futures and stock investors face even greater risk at the beginning and end of a trading day. Moreover, the bid-ask spreads are larger when the stock market becomes more volatile. The market makers widen the spreads to minimize the negative effect of dealing with informed trading. The limitation of this research is that the bid-ask spreads are calculated based on SPY, the ETF of S&P 500, which tracks the performance of S&P 500 index, rather than using individual stocks. The future research may be pursued by exploring the behavior of the other market, such as bond or options market during the higher volatility period and the relationship between markets.

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