

Trading Volume and Volatility in Single Stock Futures Markets:

Evidence from Korea

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I. Introduction

There are many studies on the relationship between trading volume and volatility in financial markets. The theoretical background for the relationship between trading volume and volatility is for the same financial market. The classical theoretical background for the same financial market is the mixture of distribution hypothesis (MDH) model by Clark (1973) and the sequential information arrival model (SIAM) by Copeland (1976, 1977). Both theories suggest that there is a positive relationship between trading volume and volatility for the same financial market.

However, there are some theoretical studies on the effect of trading volume on volatility in other markets (Stein, 1987; Harris, 1989; Subrahmanyam, 1991), but most of them are empirical analysis.

There is no definite conclusion from the theoretical point of view about the relationship between trading volume and volatility. This is because they all offer different conclusions. Harris (1989) argues that derivative markets will reduce the volatility due to order imbalances caused by uninformed traders. Stein (1987) shows that the opening of futures markets will lead

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to increased speculation and this will lead to price destabilization and decreased welfare. In Subrahmanyam's model (1991), the futures market has no effect on volatility.

In particular, there has been much research on how derivatives markets such as futures markets and options markets affect the underlying asset market. The theoretical work on this area has also been progressed (Brennan and Cao, 1996; Kraus and Smith, 1996), but most are based on empirical analysis.

Since the informed traders use the option market, the option trading volume reflects the information on the underlying stock index market (Pan and Poteshman, 2006, Ni et al., 2008, Chang et al., 2010).

In the case of the futures market, the hypothesis on whether futures trading reduces the volatility of the spot market is still controversial. Some report an empirical analysis (Bessembinder and Seguin, 1993) that derivatives trading volume reduces volatility in the spot market, and some studies report the opposite result (Kyriacou and Sarno, 1999).

In conclusion, the hypothesis on the relation between the trading volume of derivatives and the volatility of the spot market is a controversial issue of empirical analysis. A study of the relation between trading volume and volatility mentioned above was the study of the cases where the underlying assets of the futures and options are mostly stock index not individual stocks.

A study of the relationship between trading volume and volatility in single stock futures (SSF) markets is relatively rare and can be mentioned in various aspects. However, I will examine the relationship between trading volume and volatility in single stock futures (SSF) markets, rather than the fact that the introduction of SSF has the effect of stabilizing the underlying stock market.

II. Literature Review

Whether the introduction of the futures market contributed to the stabilization of the spot market has been a major concern. The results of previous studies on this are also controversial. Some studies have reported that the introduction of futures markets has increased the volatility of the spot market (Shewert, 1990; Harris, 1989; Zhong et. al., 2004) and others have reported that spot market volatility has been reduced (Lee and Ohk, 1992; Brown- Hruska and Kuserk, 1995).

The introduction of SSFs in developing countries, such as South Africa (De Beer, 2009) and Pakistan (Khan and Hijazi, 2009), are reported to reduce spot market volatility. However, another studies on Pakistan (Khan, Shah, and Abbas, 2011; Malik and Shah, 2017) report that SSFs have no effect on reducing spot volatility. Jithendranathan and Vang (2010) look at the effect of single stock futures introduction on the trading volume and volatility of underlying stocks in two different Russian markets. They report that there is a reduction in volatility after the introduction of SSF in the majority of the stocks.

Białkowski and Jakubowski (2012) investigate to what extent underlying specific properties together with contract design determine level of trading activity on single stock futures in Eurex derivative exchange. And they find that trading activity is higher for single stock futures on stock characterized by low institutional ownership, and high volume on spot market. The mispricing between spot and futures market also attracts investors to single stock futures market.

Benzennou et. al. (2013) investigate the response of the single stock futures (SSF) market to a short-selling ban in the United Kingdom from September 18, 2008 to January 16, 2009. They

explain the increased trading activity with an increase in demand from short-sellers as they shift to trading in SSF. They also find that despite the elevated SSF trading, volatility does not increase, which means that the SSF market is able to absorb the extra demand for trading without reducing market quality.

Phylaktis and Manalis (2013) examine the differences in volume, volatility and liquidity in the underlying market between intervals when futures trade and intervals when there is no futures trading using high frequency proprietary data in the Athens Stock Exchange and Athens Derivatives Exchange. They find volatility to increase when futures trade accompanied by increases in trading volume supporting the scenario that institutional investors take large positions in both derivative and the underlying markets creating price pressures. This paper has indicated that market quality might not necessarily improve with futures trading, in contrast to the results of previous studies, which applied a pre-post futures listing analysis and used lower frequency data.

III. Empirical Analysis

1. Data

In this study, intraday data such as stock price, futures price, individual stock trading volume by investor types, and futures trading volume by investor types are used. Trading volume data of single stock futures and underlying asset is categorized into individual, institutional, and foreign investors by investor type. The sample period is May 2010 to June 2016. The data frequencies of volatility and trading volume are 1 minute. The volatility and trading volume for the 15-minute, 30-minute, and 1-day periods are estimated using minute-by-minute data.

There are 102 individual stocks as the underlying assets of single stock futures. Data structure is an unbalanced-panel.

Basic statistics on volatility and trading volume by data frequency are summarized in Table 1-2. The correlation coefficients of volatility and trading volume by data frequency are summarized in Tables 3-5.

2. Model Specification

In this study, I choose the following model specification to analyze how stock trading volume and SSF trading volume affect SSF volatility and stock price volatility:

$$Vol_{it} = \alpha_{it} + \sum_{k=1}^K \beta_i^k TV_{i,t-1}^k + \sum_{l=1}^L \gamma_i^l SIG_{i,t-1}^l + \sum_{j=1}^{J-1} \delta_j D_j + \sum_{t=1}^{T-1} \theta_t D_t + \varepsilon_{it} ,$$

where, Vol_{it} is volatility of firm i 's stock return (price) or futures price at time t , $TV_{i,t-1}$ is firm i 's trading volume, D_j is a dummy variable that has a value of 1 for firm j , or 0 otherwise. And D_t is a time dummy variable. The firm i 's trading volume variable ($TV_{i,t-1}$) is classified by trader types as follows $TV_{i,t-1}^{investor}$, $investor = \{id, it, fr\}$, where, id is an individual investor, it an institutional investor, and fr a foreign investor. SIG is the degree of opinion dispersion among investors.

For individual stocks, stock returns (r) are conventionally defined as $r_t = 100 \times \ln(S_t/S_{t-1})$, S_t is stock price at time t . Vol_t^S is a type of range-based volatility of stock price developed by Garman and Klass (1980), and estimated as follows:

$$Vol_t^S = \sqrt{0.5[\ln(S_t^h/S_t^l)]^2 - (2 \ln 2 - 1)[\ln(S_t^c/S_t^o)]^2} ,$$

where, S_t^h is the highest price of individual stock (or SSF) during trading period t , S_t^l the

lowest price, S_t^o the opening price, and S_t^c the closing price during trading period t . The trading period t is 15 minutes, 30 minutes, or one day. Likewise, Vol_t^F is defined and estimated in the same way for the SSF. I use the standard deviation (σ_t) of the stock price return as another volatility measure (Vol_t^R) for individual stocks.

According to the sequential information arrival model (SIAM) of Copeland (1976), there is a positive correlation between trading volume and volatility (or the absolute value of price change). When traders show the same opinion on new information, the positive correlation becomes bigger. When the discrepancy about new information among traders becomes bigger, the positive correlation becomes smaller. When a new information is transmitted to all traders at the same time, the trading volume increases as the disagreement among traders increases, and there may be a negative correlation between trading volume and volatility. Therefore, the level of disagreement among investors is reflected in the trading volume and affects price volatility. In this study, I use the standard deviation of trading volume as a measure of disagreement of investors.

And they are denoted as $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs, where, $investor = \{id, it, fr\}$, id is an individual investor, it an institutional investor, and fr a foreign investor.

As documented in previous studies such as Bessembinder and Seguin (1992, 1993), I decompose each trading volume into expected and unexpected components. The trading volume decomposition is done through AR(1) model specification with various dummy variables. The unexpected components are residuals of the estimation, and they are interpreted as shocks of the trading activity. The expected components of each series are denoted as

$E^{S,investor}$ for stock, $E^{F,investor}$ for futures, and the unexpected parts of trading volume $U^{S,investor}$ for stock, $U^{F,investor}$ for futures.

3. Empirical Results

First, let us examine the relationship between volatility of individual stocks and trading volume (Tables 6 and 7). Two kinds of volatility of individual stock are estimated; the range-based volatility of individual stock (Vol^S) and the sample standard deviation of individual stock returns (Vol^R).

In the case of daily volatility of individual stocks Vol^S , the relationship between the daily volatility of individual stock and total trading volume of SSFs is negative (Table 6). However, in the case of individual stock volatility estimated by the frequency of 30 minutes or 15 minutes, the total trading volume of individual stocks (TV^S) and the total trading volume of SSF (TV^F) are both positively (+) related to the volatility of individual stock (Vol^S).

In addition, there is a positive (+) relationship between stock volatility and the degree of opinion dispersion (SIG^S , SIG^F) in total trading volume of stock and SSF.

As for the relationship between individual stock volatility and trading volume by investor types, stock trading volume by investor shows a positive (+) relationship with stock volatility as a whole (Table 6).

In addition, the increase in SSF trading volume by investor types appears to lead to an increase in volatility of underlying stock. However, the increase in futures trading volume of some investors seems to reduce the volatility of underlying stocks. The increase in institutional investors' futures trading volume for the 30-minute and 15-minute frequencies appears to result in a decrease in individual stock volatility. The increase in futures trading volume of individual investors also shows that individual stock volatility is reduced.

And the degree of opinion dispersion in investor type's trading volume shows a positive (+) correlation between individual stock volatility (Table 6).

Let's look at the relationship between the volatility (Vol^R) estimated by the sample standard deviation of individual stock returns and the trading volume by trader types (Table 7). With a few exceptions, it is overall similar to the case of range-based volatility (Vol^S). Especially, in case of frequency data of 30 minutes and 15 minutes, the increase of stock trading volume of foreigners causes decrease in stock volatility (Vol^R). Also, the increase in the futures trading volume ($TV_{t-1}^{F,fr}$) of foreign investors has also been shown to result in a decrease in stock volatility (Vol^R).

The relationship between SSF price volatility and trading volume is summarized in Table 8. The total SSF trading volume and the total individual stock trading volume have a positive (+) relationship with the SSF volatility for 30-minute and 15-minute frequency data, and a negative (-) relationship with the daily SSF volatility. The increase in the degree of opinion dispersion of stock trading and SSF trading has all shown to increase SSF volatility.

Let's take a look at the effect of trading volume by investor types on SSF volatility (Table 8). For daily data, individual investors' stock trading volume and SSF trading volume are found to reduce SSF volatility. 30-minute and 15-minute individual investors' stock trading volume is found to increase SSF volatility.

For all frequencies, such as daily, 30 minutes, and 15 minutes, stock trading volume and SSF trading volume of institutional and foreign investors increase SSF volatility.

The increase in the degree of opinion dispersion of stock trading and SSF trading by trader types has all shown to increase SSF volatility (Table 8).

The effects of expected and unexpected parts of trading volume on volatility are summarized

in (Table 9, 10, 11). First, the effect of disaggregated trading volume on volatility (Vol^S , Vol^R) is summarized in Tables 9 and 10. Both the expected and unexpected parts of total trading volume stocks and SSFs increase individual stock volatility.

The degree of disagreement is positively correlated with stock volatility.

Regarding the trading volume by investor types, the expected trading volume of stocks decreases the stock volatility (Vol^S) but increases the stock volatility for 15-minute and 30-minute frequency data. The expected trading volume of the SSF has been shown to increase stock volatility as a whole (Table 9).

For all frequencies, such as daily, 30 minutes, and 15 minutes, the unexpected trading volume of stocks increases stock volatility. And the unexpected trading volume of SSF shows that stock volatility increases overall.

The degree of disagreement indicates a positive (+) relationship with stock volatility as a whole. However, exceptionally, the level of disagreement in foreigners' stock trading volume and stock volatility show a negative (-) relationship.

The effects of the predicted trading volume and the unexpected trading volume on the volatility (Vol^R) estimated by the sample standard deviation of the stock return are summarized in Table 10. The expected stock trading volume and the expected SSF trading volume of foreign investors show a negative (-) relationship with stock return volatility (Vol^R). In addition, the unexpected SSF trading volume of institutional investors and foreign investors also shows a negative relation with stock return volatility (Vol^R).

Table 11 shows the effect of the expected trading volume and the unexpected trading volume on the SSF volatility (Vol^F). Both the expected trading volume and the unexpected trading volume of stocks and SSFs are positively correlated with SSF volatility. The increase in degree of opinion dispersion has been shown to increase SSF volatility as a whole. Unusual is that the

degree of opinion dispersion of institutional investors and foreign investors in SSF trading shows a negative relationship with SSF volatility.

Until now, the relationship between trading volume and volatility of 102 individual stocks and SSF has been estimated by linear panel regression. For reference, the results of estimating basic ordinary regression for individual stocks of Samsung Electronics are summarized in Tables 12-17. They show similar results with the panel regression.

IV. Conclusion

This study analyzes the relationship between single stock futures volatility and trading volume, using minute-by-minute data of the single stock futures data from May 2010 to June 2016. The trading volume is divided according to investor type such as individual, institutional, and foreign investors. The volatility and trading volume for the 15-minute, 30-minute, and 1-day periods are estimated using minute-by-minute data. There are 102 individual stocks as the underlying assets of single stock futures. Data structure is an unbalanced-panel. Linear panel model specifications are estimated.

The volatility of single stock futures is estimated by Garman-Klass range-based volatility (denoted as GK volatility), and the volatility of the underlying single stock is estimated not only by the range-based volatility of Garman-Klass, but also by the sample standard deviation of stock returns (historical volatility). The degree of discrepancy among investors' opinion is estimated by the standard deviation of trading volume.

The volatility (GK volatility, historical volatility) of individual stocks has a positive relationship with total trading volume of individual stocks and total trading volume of single stock futures. However, the daily volatility of individual stocks is negatively related with the

total trading volume of single stock futures. In addition, the volatility of individual stocks increases as the degree of discrepancy of market expectations increases.

The volatility of single stock futures (15 minutes, 30 minutes) also shows a positive (+) relationship with total trading volume of individual stocks and total trading volume of single stock futures. The daily volatility of single stock futures was found to be negative (-) with the total trading volume of single stock futures. In addition, the volatilities of both individual stocks and single stock futures increases as the degree of discrepancy of the expectations of market participants.

The effect of daily trading volume by investor type on the volatility of single stock futures and underlying assets is as follows. The individual stock trading volume of individual investors has been shown to reduce individual stock volatility and GK volatility of single stock futures. On the other hand, institutional investors' trading volume increases individual stock volatility and GK volatility of single stock futures. Foreigner's trading volume increases the historical volatility.

The effects of 15-minute and 30-minute trading volume on single stock futures and volatility of underlying assets are as follows. Foreigner's stock trading volume reduces historical volatility of individual stocks, while GK volatility of stocks decreases. The stock trading volume of individuals and institutions increases both historical volatility and GK volatility of stocks. Institutional investors' single stock futures trading volume was found to reduce both GK volatility and historical volatility of stocks. On the other hand, individual investors' futures trading volume increases both GK volatility and historical volatility of stocks.

And the greater the discrepancy of investors' expectation, the more overall volatility increases except for some exceptions.

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Tables

Table 1: Summary Statistics of Volatilities

Frequency	variable	Mean	Median	Max	Min	Std.	Skew.	Kurt.	Obs.
Daily	Vol^S	0.02	0.01	0.17	0.00	0.01	2.93	23.52	68,087
	Vol^R	0.17	0.15	0.89	0.00	0.07	1.36	5.87	68,087
	Vol^F	0.02	0.01	0.20	0.00	0.01	3.39	31.35	68,087
30 Min		4.2E-3	3.5E-3	0.11	0.00	3.0E-3	3.28	34.85	727,306
	Vol^S	3				3			
	Vol^R	0.16	0.14	3.19	0.00	0.08	1.85	15.26	727,351
	Vol^F	0.00	0.00	0.20	0.00	0.00	5.17	105.4	727,256
15 min		2.9E-3	2.4E-3	0.10	0.00	2.2E-3	3.27	38.24	
	Vol^S	3				3			1,273,523
		0.16	0.14	4.89	0.00	0.09	2.37	28.85	
	Vol^R								1,310,681
	Vol^F	1.9E-3	1.3E-3	0.16	0.00	2.2E-3	5.91	144.7	
		3				3	1	1,310,176	

Note: Vol^S is a Garman-Klass range-based volatility measure of stock prices, Vol^R volatility of stock returns measured as a sample standard deviation, Vol^F a Garman-Klass range-based volatility measure of futures prices.

Table 2: Summary Statistics of Trading Volume

Frequency	variable	Mean	Median	Max	Min	Std.	Skew.	Kurt.	Obs.
Daily	TV^S	16.14	16.14	21.26	10.43	1.11	-0.03	3.08	68,087
	$TV^{S,id}$	15.10	15.17	20.70	9.12	1.40	-0.15	3.02	68,087
	$TV^{S,it}$	14.75	14.76	21.25	4.34	1.14	-0.40	4.56	68,087
	$TV^{S,fr}$	14.85	14.83	19.61	0.00	1.12	-0.06	3.31	68,087
	TV^F	8.66	8.73	14.23	1.10	1.62	-0.42	3.89	68,087
	$TV^{F,id}$	8.01	8.06	14.09	0.00	1.72	-0.27	3.61	68,087
	$TV^{F,it}$	6.86	7.06	12.43	0.00	1.81	-1.05	5.34	68,087
	$TV^{F,fr}$	6.75	7.19	12.49	0.00	2.22	-1.12	4.37	68,087
30Min	TV^S	13.54	13.52	19.90	7.43	1.17	0.10	2.99	727,351
	$TV^{S,id}$	12.47	12.51	19.84	3.33	1.48	-0.09	3.09	727,351
	$TV^{S,it}$	12.15	12.16	18.48	0.00	1.24	-0.43	5.74	727,351
	$TV^{S,fr}$	12.12	12.15	19.36	0.00	1.40	-1.42	13.80	727,351
	TV^F	6.03	6.07	12.73	0.00	1.71	-0.09	2.96	727,351
	$TV^{F,id}$	5.33	5.38	12.44	0.00	1.86	-0.11	3.06	727,351
	$TV^{F,it}$	3.72	4.08	11.45	0.00	2.28	-0.27	2.17	727,351
	TV^S	4.03	4.39	11.14	0.00	2.24	-0.39	2.33	727,351
15 min	TV^S	12.88	12.86	19.60	6.28	1.19	0.12	3.00	1,310,681
	$TV^{S,id}$	11.80	11.84	19.55	0.00	1.52	-0.14	3.25	1,310,681
	$TV^{S,it}$	11.47	11.49	18.46	0.00	1.27	-0.48	5.93	1,310,681
	$TV^{S,fr}$	11.42	11.45	19.36	0.00	1.45	-1.33	12.00	1,310,681
	TV^F	5.46	5.46	12.34	0.00	1.66	0.03	2.85	1,310,681
	$TV^{F,id}$	4.76	4.79	12.13	0.00	1.83	-0.04	2.98	1,310,681
	$TV^{F,it}$	2.99	3.26	10.78	0.00	2.25	0.02	1.90	1,310,681
	TV^S	3.42	3.74	11.14	0.00	2.16	-0.20	2.09	1,310,681

Note: $TV^{S,investor}$ is a natural logarithm of stock trading volume, where $investor = \{id, it, fr\}$, id is an individual investor, it an institutional investor, and fr a foreign investor. $TV^{F,investor}$ a natural logarithm of futures trading volume.

Table 3: Correlation Coefficients of Variables (Daily)

	Vol^S	Vol^R	Vol^F	TV^S	$TV^{S,id}$	$TV^{S,it}$	$TV^{S,fr}$	TV^F	$TV^{F,id}$	$TV^{F,it}$	$TV^{F,fr}$
Vol^S	1.00	0.47	0.87	0.26	0.19	0.15	0.10	0.18	0.28	0.23	0.15
Vol^R	0.47	1.00	0.42	0.15	0.13	0.06	0.01	0.10	0.19	0.13	0.05
Vol^F	0.87	0.42	1.00	0.29	0.24	0.19	0.14	0.23	0.32	0.25	0.18
TV^S	0.26	0.15	0.29	1.00	0.72	0.62	0.40	0.71	0.93	0.90	0.85
$TV^{S,id}$	0.19	0.13	0.24	0.72	1.00	0.80	0.70	0.98	0.72	0.65	0.57
$TV^{S,it}$	0.15	0.06	0.19	0.62	0.80	1.00	0.59	0.86	0.60	0.56	0.52
$TV^{S,fr}$	0.10	0.01	0.14	0.40	0.70	0.59	1.00	0.76	0.38	0.41	0.37
TV^F	0.18	0.10	0.23	0.71	0.98	0.86	0.76	1.00	0.70	0.65	0.58
$TV^{F,id}$	0.28	0.19	0.32	0.93	0.72	0.60	0.38	0.70	1.00	0.78	0.66
$TV^{F,it}$	0.23	0.13	0.25	0.90	0.65	0.56	0.41	0.65	0.78	1.00	0.76
$TV^{F,fr}$	0.15	0.05	0.18	0.85	0.57	0.52	0.37	0.58	0.66	0.76	1.00

Note: Vol^S is a Garman-Klass range-based volatility measure of stock prices, Vol^R volatility of stock returns measured as a sample standard deviation, Vol^F a Garman-Klass range-based volatility measure of futures prices. $TV^{S,investor}$ is a natural logarithm of stock trading volume, where $investor = \{id, it, fr\}$, id is an individual investor, it an institutional investor, and fr a foreign investor. $TV^{F,investor}$ a natural logarithm of futures trading volume.

Table 4: Correlation Coefficients of Variables (30 minutes)

	Vol^S	Vol^R	Vol^F	TV^S	$TV^{S,id}$	$TV^{S,it}$	$TV^{S,fr}$	TV^F	$TV^{F,id}$	$TV^{F,it}$	$TV^{F,fr}$
Vol^S	1.00	0.62	0.71	0.30	0.23	0.21	0.16	0.24	0.33	0.17	0.19
Vol^R	0.62	1.00	0.40	0.19	0.16	0.08	0.04	0.15	0.23	0.13	0.10
Vol^F	0.71	0.40	1.00	0.31	0.39	0.32	0.30	0.40	0.35	0.18	0.20
TV^S	0.30	0.19	0.31	1.00	0.62	0.44	0.34	0.62	0.91	0.84	0.76
$TV^{S,id}$	0.23	0.16	0.39	0.62	1.00	0.59	0.62	0.95	0.63	0.49	0.43
$TV^{S,it}$	0.21	0.08	0.32	0.44	0.59	1.00	0.46	0.71	0.41	0.35	0.34
$TV^{S,fr}$	0.16	0.04	0.30	0.34	0.62	0.46	1.00	0.73	0.32	0.28	0.29
TV^F	0.24	0.15	0.40	0.62	0.95	0.71	0.73	1.00	0.61	0.50	0.44
$TV^{F,id}$	0.33	0.23	0.35	0.91	0.63	0.41	0.32	0.61	1.00	0.68	0.56
$TV^{F,it}$	0.17	0.13	0.18	0.84	0.49	0.35	0.28	0.50	0.68	1.00	0.61
$TV^{F,fr}$	0.19	0.10	0.20	0.76	0.43	0.34	0.29	0.44	0.56	0.61	1.00

Table 5: Correlation Coefficients of Variables (15 minutes)

	Vol^S	Vol^R	Vol^F	TV^S	$TV^{S,id}$	$TV^{S,it}$	$TV^{S,fr}$	TV^F	$TV^{F,id}$	$TV^{F,it}$	$TV^{F,fr}$
Vol^S	1.00	0.66	0.62	0.30	0.21	0.20	0.15	0.22	0.32	0.17	0.19
Vol^R	0.66	1.00	0.38	0.19	0.16	0.08	0.04	0.14	0.22	0.11	0.09
Vol^F	0.62	0.38	1.00	0.31	0.38	0.32	0.30	0.39	0.33	0.16	0.20
TV^S	0.30	0.19	0.31	1.00	0.59	0.39	0.32	0.59	0.91	0.82	0.73
$TV^{S,id}$	0.21	0.16	0.38	0.59	1.00	0.51	0.57	0.93	0.59	0.45	0.39
$TV^{S,it}$	0.20	0.08	0.32	0.39	0.51	1.00	0.42	0.66	0.35	0.31	0.30
$TV^{S,fr}$	0.15	0.04	0.30	0.32	0.57	0.42	1.00	0.71	0.29	0.25	0.28
TV^F	0.22	0.14	0.39	0.59	0.93	0.66	0.71	1.00	0.58	0.46	0.41
$TV^{F,id}$	0.32	0.22	0.33	0.91	0.59	0.35	0.29	0.58	1.00	0.65	0.53
$TV^{F,it}$	0.17	0.11	0.16	0.82	0.45	0.31	0.25	0.46	0.65	1.00	0.57
$TV^{F,fr}$	0.19	0.09	0.20	0.73	0.39	0.30	0.28	0.41	0.53	0.57	1.00

Table 6: Estimation Results of Linear Panel Regression: Dependent Variable = Vol^S

	Regressors	Daily	30 Minutes	15 Minutes
Total Trading Volume	c	1.6E-2 ***	-4.8E-3 ***	-2.4E-3 ***
	TV_{t-1}^S	-7.4E-5	5.8E-4 ***	3.7E-4 ***
	TV_{t-1}^F	-1.1E-4 ***	8.8E-5 ***	4.3E-5 ***
	SIG^S	1.1E-9 ***	1.5E-9 ***	1.6E-9 ***
	SIG^F	1.3E-5 ***	2.4E-6 ***	1.5E-6 ***
	Adj-R ²	0.45	0.27	0.24
Trading Volume by Investors	c	1.4E-2 ***	-2.4E-3 ***	-8.7E-4 ***
	$TV_{t-1}^{S,id}$	-1.5E-4 ***	2.1E-4 ***	1.4E-4 ***
	$TV_{t-1}^{S,it}$	2.2E-4 ***	1.5E-4 ***	9.4E-5 ***
	$TV_{t-1}^{S,fr}$	2.5E-5	7.9E-5 ***	4.2E-5 ***
	$TV_{t-1}^{F,id}$	-2.2E-4 ***	8.6E-5 ***	5.1E-5 ***
	$TV_{t-1}^{F,it}$	6.6E-5 **	-1.1E-5 ***	-7.8E-6 ***
	$TV_{t-1}^{F,fr}$	9.1E-6	3.5E-5 ***	1.3E-5 ***
	$SIG^{S,id}$	2.4E-8 ***	6.3E-9 ***	5.3E-9 ***
	$SIG^{S,it}$	5.2E-10 ***	1.9E-9 ***	1.8E-9 ***
	$SIG^{S,fr}$	5.9E-10 ***	7.7E-11 ***	9.5E-11 ***
	$SIG^{F,id}$	6.7E-6 ***	9.7E-7 ***	4.8E-7 ***
	$SIG^{F,it}$	5.5E-6 ***	1.3E-6 ***	9.5E-7 ***
	$SIG^{F,fr}$	2.3E-6 ***	3.2E-6 ***	2.2E-6 ***
	Adj-R ²	0.47	0.28	0.26

Note: Estimation results are from the following linear panel regression model:

$$Vol_{it} = \alpha_{it} + \sum_{k=1}^K \beta_i^k TV_{i,t-1}^k + \sum_{l=1}^L \gamma_i^l SIG_{i,t-1}^l + \sum_{j=1}^{J-1} \delta_j D_j + \sum_{t=1}^{T-1} \theta_t D_t + \varepsilon_{it} ,$$

where, Vol_{it} is range-based volatility of firm i's stock price at time t, TV_{it-1} is firm i's trading volume, D_j is a dummy variable that has a value of 1 for firm j, or 0 otherwise. And D_t is a time dummy variable. The firm i's stock trading volume variable (TV_{it-1}) is classified by trader types as follows $TV_{t-1}^{S,investor}$, investor={id,it,fr}, where, id is an individual investor, it an institutional investor, and fr a foreign investor. The trading volume of SSF is denoted as $TV_{t-1}^{F,investor}$. $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 7: Estimation Results of Linear Panel Regression: Dependent Variable = Vol^R

Regressors		Daily	30 Minutes	15 Minutes
Total Trading Volume	c	1.5E-1 ***	4.6E-2 ***	4.4E-2 ***
	TV_{t-1}^S	1.4E-3 ***	5.4E-3 ***	6.7E-3 ***
	TV_{t-1}^F	-1.4E-3 ***	1.1E-3 ***	1.0E-3 ***
	SIG^S	2.6E-9 ***	2.9E-8 ***	2.8E-8 ***
	SIG^F	7.0E-5 ***	5.1E-5 ***	4.8E-5 ***
	Adj-R ²	0.51	0.37	0.32
Trading Volume by Investors	c	1.4E-1 ***	4.9E-2 ***	5.4E-2 ***
	$TV_{t-1}^{S,id}$	3.9E-4	2.2E-3 ***	2.8E-3 ***
	$TV_{t-1}^{S,it}$	5.1E-4	3.5E-3 ***	3.6E-3 ***
	$TV_{t-1}^{S,fr}$	1.7E-3 ***	-9.7E-4 ***	-5.7E-4 ***
	$TV_{t-1}^{F,id}$	-3.7E-3 ***	4.0E-3 ***	3.5E-3 ***
	$TV_{t-1}^{F,it}$	3.0E-3 ***	-1.6E-3 ***	-1.3E-3 ***
	$TV_{t-1}^{F,fr}$	-8.6E-4 ***	-1.9E-3 ***	-1.8E-3 ***
	$SIG^{S,id}$	4.1E-8 ***	7.3E-8 ***	7.3E-8 ***
	$SIG^{S,it}$	1.7E-9 ***	6.1E-8 ***	4.7E-8 ***
	$SIG^{S,fr}$	3.0E-10	6.9E-9 ***	1.2E-8 ***
	$SIG^{F,id}$	9.3E-5 ***	5.5E-5 ***	4.6E-5 ***
	$SIG^{F,it}$	-5.2E-6	-6.8E-6 ***	4.8E-6 ***
	$SIG^{F,fr}$	-2.1E-5 ***	4.2E-5 ***	5.3E-5 ***
	Adj-R ²	0.51	0.38	0.33

Note: Estimation results are from the following linear panel regression model:

$$Vol_{it} = \alpha_{it} + \sum_{k=1}^K \beta_i^k TV_{i,t-1}^k + \sum_{l=1}^L \gamma_i^l SIG_{i,t-1}^l + \sum_{j=1}^{J-1} \delta_j D_j + \sum_{t=1}^{T-1} \theta_t D_t + \varepsilon_{it} ,$$

where, Vol_{it} is a sample standard deviation of firm i 's stock returns at time t , TV_{it-1} is firm i 's trading volume, D_j is a dummy variable that has a value of 1 for firm j , or 0 otherwise. And D_t is a time dummy variable. The firm i 's stock trading volume variable (TV_{it-1}) is classified by trader types as follows $TV_{t-1}^{S,investor}$, investor={id,it,fr}, where, id is an individual investor, it an institutional investor, and fr a foreign investor. The trading volume of SSF is denoted as $TV_{t-1}^{F,investor}$. $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 8: Estimation Results of Linear Panel Regression: Dependent Variable = Vol^F

		Regressors	Daily	30 Minutes	15 Minutes
Total Trading Volume		c	1.5E-2 ***	-6.2E-3 ***	-3.1E-3 ***
		TV_{t-1}^S	-5.9E-6	5.5E-4 ***	3.6E-4 ***
		TV_{t-1}^F	-1.5E-4 ***	2.4E-4 ***	1.5E-4 ***
		SIG^S	9.4E-10 ***	1.2E-9 ***	5.8E-10 ***
		SIG^F	1.3E-5 ***	2.7E-6 ***	1.9E-6 ***
		Adj-R ²	0.42	0.28	0.26
Trading Volume by Investors		c	1.3E-2 ***	-3.8E-3 ***	-1.5E-3 ***
		$TV_{t-1}^{S,id}$	-1.4E-4 ***	2.1E-4 ***	1.4E-4 ***
		$TV_{t-1}^{S,it}$	2.2E-4 ***	1.3E-4 ***	8.4E-5 ***
		$TV_{t-1}^{S,fr}$	8.5E-5	9.0E-5 ***	5.3E-5 ***
		$TV_{t-1}^{F,id}$	-2.1E-4 ***	1.6E-4 ***	1.0E-4 ***
		$TV_{t-1}^{F,it}$	1.7E-5	1.7E-5 ***	1.7E-5 ***
		$TV_{t-1}^{F,fr}$	1.7E-5	7.3E-5 ***	4.5E-5 ***
		$SIG^{S,id}$	2.3E-8 ***	4.9E-9 ***	2.8E-9 ***
		$SIG^{S,it}$	3.0E-10 ***	8.4E-10 ***	7.0E-11 **
		$SIG^{S,fr}$	1.1E-9 ***	2.0E-10 ***	1.4E-10 ***
		$SIG^{F,id}$	6.8E-6 ***	1.6E-6 ***	1.2E-6 ***
		$SIG^{F,it}$	6.1E-6 ***	2.0E-6 ***	1.5E-6 ***
		$SIG^{F,fr}$	2.4E-6 ***	3.2E-6 ***	2.5E-6 ***
		Adj-R ²	0.44	0.28	0.27

Note: Estimation results are from the following linear panel regression model:

$$Vol_{it} = \alpha_{it} + \sum_{k=1}^K \beta_i^k TV_{i,t-1}^k + \sum_{l=1}^L \gamma_i^l SIG_{i,t-1}^l + \sum_{j=1}^{J-1} \delta_j D_j + \sum_{t=1}^{T-1} \theta_t D_t + \varepsilon_{it} ,$$

where, Vol_{it} is range-based volatility of firm i 's futures price at time t , TV_{it-1} is firm i 's trading volume, D_j is a dummy variable that has a value of 1 for firm j , or 0 otherwise. And D_t is a time dummy variable. The firm i 's stock trading volume variable (TV_{it-1}) is classified by trader types as follows $TV_{t-1}^{S,investor}$, investor={id,it,fr}, where, id is an individual investor, it an institutional investor, and fr a foreign investor. The trading volume of SSF is denoted as $TV_{t-1}^{F,investor}$. $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 9: Estimation Results of Linear Panel Regression: Dependent Variable = Vol^S

Regressors		Daily		30 Minutes		15 Minutes	
Decom- Posed Trading Volume	c	-0.25	***	-0.01	***	-0.01	***
	E^S	0.01	*	8.7E-4	***	6.0E-4	***
	E^F	0.01	***	2.6E-4	***	1.5E-4	***
	U^S	0.01	***	1.7E-3	***	1.0E-3	***
	U^F	1.4E-3	***	2.4E-4	***	1.3E-4	***
	SIG^S	1.5E-10	***	4.8E-10	***	6.0E-10	***
	SIG^F	2.6E-6	***	8.8E-7	***	5.6E-7	***
Adj-R ²		0.55		0.36		0.32	
Decom- Posed Trading Volume by Investors	C	1.38	***	-0.01	***	-2.9E-3	***
	$E^{S,id}$	-0.04	***	3.7E-4	***	2.6E-4	***
	$E^{S,it}$	-0.01	***	1.5E-4	***	9.0E-5	***
	$E^{S,fr}$	-0.05	***	1.2E-4	***	7.8E-5	***
	$E^{F,id}$	0.01	***	1.2E-4	***	7.0E-5	***
	$E^{F,it}$	1.1E-3		3.5E-5	***	2.4E-5	***
	$E^{F,fr}$	-1.8E-3	**	1.6E-4	***	9.6E-5	***
	$U^{S,id}$	1.4E-3	***	7.7E-4	***	4.3E-4	***
	$U^{S,it}$	2.1E-3	***	4.0E-4	***	2.4E-4	***
	$U^{S,fr}$	6.5E-4	***	2.3E-4	***	1.7E-4	***
	$U^{F,id}$	1.5E-3	***	1.1E-4	***	5.7E-5	***
	$U^{F,it}$	-9.6E-5	***	4.1E-5	***	3.3E-5	***
	$U^{F,fr}$	2.7E-4	***	1.2E-4	***	7.7E-5	***
	$SIG^{S,id}$	1.7E-8	***	4.4E-9	***	3.7E-9	***
	$SIG^{S,it}$	2.2E-10	***	-1.1E-10		3.4E-10	***
	$SIG^{S,fr}$	-8.6E-10	***	-4.1E-11	*	-7.9E-11	***
	$SIG^{F,id}$	-1.3E-6	***	4.1E-7	***	2.1E-7	***
	$SIG^{F,it}$	-1.2E-7		-2.2E-7	***	-1.3E-7	***
	$SIG^{F,fr}$	-4.3E-6	***	2.7E-7	***	1.7E-7	***
	Adj-R ²		0.56		0.26		0.32

Note: Estimation results are from the following linear panel regression model:

$$Vol_{it} = \alpha_{it} + \sum_{k=1}^K \beta_i^k TV_{i,t-1}^k + \sum_{l=1}^L \gamma_i^l SIG_{i,t-1}^l + \sum_{j=1}^{J-1} \delta_j D_j + \sum_{t=1}^{T-1} \theta_t D_t + \varepsilon_{it} ,$$

where, Vol_{it} is range-based volatility of firm i 's stock price at time t , UE_i^k is firm i 's decomposed trading volume. The expected components of trading volume are denoted as E and the unexpected

parts of trading volume U . D_j is a dummy variable that has a value of 1 for firm j , or 0 otherwise. And D_t is a time dummy variable. There are three trader types such as individual investors (id), institutional investors (it), and foreign investors (fr). $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 10: Estimation Results of Linear Panel Regression: Dependent Variable = Vol^R

	Regressors	Daily	30 Minutes	15 Minutes
Decom- Posed Trading Volume	c	2.082 ***	2.0E-3	-0.01 *
	E^S	-0.180 ***	0.01 ***	0.01 ***
	E^F	0.113 ***	2.8E-3 ***	3.1E-3 ***
	U^S	0.008 ***	0.02 ***	0.02 ***
	U^F	0.003 ***	1.6E-3 ***	1.9E-3 ***
	SIG^S	1.2E-9 ***	1.9E-8 ***	2.1E-8 ***
	SIG^F	5.2E-5 ***	3.9E-5 ***	3.3E-5 ***
	Adj-R ²	0.51	0.38	0.33
Decom- Posed Trading Volume by Investors	C	7.546 ***	4.4E-3	3.8E-3
	$E^{S,id}$	0.037	3.6E-3 ***	4.8E-3 ***
	$E^{S,it}$	-0.015	4.9E-3 ***	4.8E-3 ***
	$E^{S,fr}$	-0.615 ***	-1.3E-3 ***	-6.7E-4 ***
	$E^{F,id}$	0.297 ***	0.01 ***	0.01 ***
	$E^{F,it}$	-0.168 ***	-3.4E-3 ***	-2.7E-3 ***
	$E^{F,fr}$	0.029 ***	-3.7E-3 ***	-3.5E-3 ***
	$U^{S,id}$	0.001 ***	0.01 ***	0.01 ***
	$U^{S,it}$	0.006 ***	0.01 ***	0.01 ***
	$U^{S,fr}$	-0.004 ***	1.7E-3 ***	2.1E-3 ***
	$U^{F,id}$	0.010 ***	2.1E-3 ***	1.8E-3 ***
	$U^{F,it}$	-0.004 ***	-5.6E-4 ***	-2.2E-4 ***
	$U^{F,fr}$	-0.003 ***	-3.9E-4 ***	-3.5E-6
	$SIG^{S,id}$	3.3E-8 ***	5.9E-8 ***	5.7E-8 ***
	$SIG^{S,it}$	8.9E-10 **	3.6E-8 ***	3.3E-8 ***
	$SIG^{S,fr}$	1.4E-9	6.7E-9 ***	1.1E-8 ***
	$SIG^{F,id}$	5.7E-5 ***	4.6E-5 ***	3.7E-5 ***
	$SIG^{F,it}$	1.8E-5 ***	-7.5E-6 ***	-2.4E-6
	$SIG^{F,fr}$	1.1E-6	3.6E-5 ***	3.9E-5 ***
	Adj-R ²	0.53	0.39	0.33

Note: Estimation results are from the following linear panel regression model:

$$Vol_{it} = \alpha_{it} + \sum_{k=1}^K \beta_i^k TV_{i,t-1}^k + \sum_{l=1}^L \gamma_i^l SIG_{i,t-1}^l + \sum_{j=1}^{J-1} \delta_j D_j + \sum_{t=1}^{T-1} \theta_t D_t + \varepsilon_{it} ,$$

where, Vol_{it} is a sample standard deviation of firm i 's stock return at time t , UE_i^k is firm i 's decomposed trading volume. The expected components of trading volume are denoted as E and

the unexpected parts of trading volume U . D_j is a dummy variable that has a value of 1 for firm j , or 0 otherwise. And D_t is a time dummy variable. There are three trader types such as individual investors (id), institutional investors (it), and foreign investors (fr). $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 11: Estimation Results of Linear Panel Regression: Dependent Variable = Vol^F

Regressors		Daily	30 Minutes	15 Minutes
Decom- Posed Trading Volume	c	-0.15 ***	-0.01 ***	-0.01 ***
	E^S	0.01	6.8E-4 ***	4.6E-4 ***
	E^F	0.01 ***	6.4E-4 ***	4.6E-4 ***
	U^S	0.01 ***	1.0E-3 ***	5.9E-4 ***
	U^F	1.9E-3 ***	6.8E-4 ***	4.4E-4 ***
	SIG^S	-2.3E-11	5.7E-10 ***	2.7E-10 ***
	SIG^F	1.2E-6 ***	2.8E-7 ***	2.4E-7 ***
Adj-R ²		0.53	0.38	0.35
Decom- Posed Trading Volume by Investors	C	1.79 ***	-0.01 ***	-2.6E-3 ***
	$E^{S,id}$	-0.04 ***	2.5E-4 ***	1.7E-4 ***
	$E^{S,it}$	-0.01 ***	8.2E-5 ***	5.8E-5 ***
	$E^{S,fr}$	-0.08 ***	1.4E-4 ***	9.1E-5 ***
	$E^{F,id}$	0.01 ***	3.4E-4 ***	2.3E-4 ***
	$E^{F,it}$	4.8E-3 ***	1.1E-4 ***	9.3E-5 ***
	$E^{F,fr}$	-1.8E-3 *	2.5E-4 ***	1.9E-4 ***
	$U^{S,id}$	1.8E-3 ***	4.2E-4 ***	2.4E-4 ***
	$U^{S,it}$	1.6E-3 ***	2.0E-4 ***	1.1E-4 ***
	$U^{S,fr}$	7.9E-4 ***	1.5E-4 ***	9.3E-5 ***
	$U^{F,id}$	1.7E-3 ***	4.1E-4 ***	2.5E-4 ***
	$U^{F,it}$	-2.0E-5	1.1E-4 ***	8.9E-5 ***
	$U^{F,fr}$	3.3E-4 ***	2.1E-4 ***	1.4E-4 ***
	$SIG^{S,id}$	1.5E-8 ***	4.1E-9 ***	2.2E-9 ***
	$SIG^{S,it}$	4.5E-11	-3.1E-10 ***	-3.1E-10 ***
	$SIG^{S,fr}$	-4.7E-10 ***	7.5E-11 ***	7.3E-11 ***
	$SIG^{F,id}$	-2.3E-6 ***	1.8E-7 ***	3.1E-7 ***
	$SIG^{F,it}$	-5.4E-7	-7.9E-7 ***	-5.5E-7 ***
	$SIG^{F,fr}$	-5.3E-6 ***	-1.1E-6 ***	-7.5E-7 ***
Adj-R ²		0.54	0.38	0.36

Note: Estimation results are from the following linear panel regression model:

$$Vol_{it} = \alpha_{it} + \sum_{k=1}^K \beta_i^k UE_{it}^k + \sum_{l=1}^L \gamma_i^l SIG_{i,t-1}^l + \sum_{j=1}^{J-1} \delta_j D_j + \sum_{t=1}^{T-1} \theta_t D_t + \varepsilon_{it} ,$$

where, Vol_{it} is range-based volatility of firm i 's futures price at time t , UE_i^k is firm i 's decomposed trading volume. The expected components of trading volume are denoted as E and the unexpected

parts of trading volume U . D_j is a dummy variable that has a value of 1 for firm j , or 0 otherwise. And D_t is a time dummy variable. There are three trader types such as individual investors (id), institutional investors (it), and foreign investors (fr). $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Figure 1 Time-series of Variables (Daily)

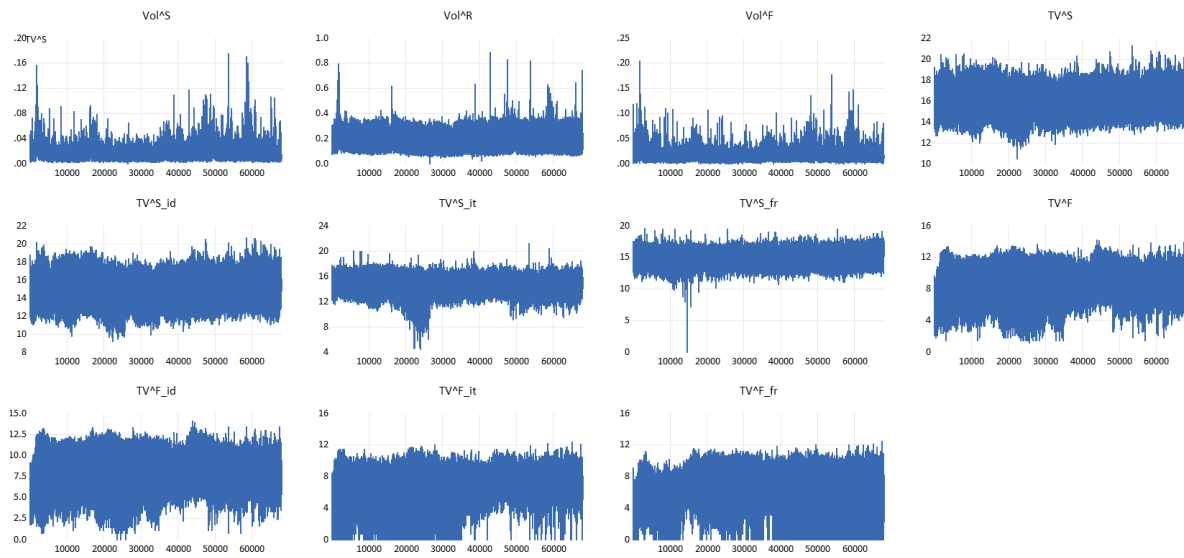


Figure 2 Time-series of Variables (30 Minutes)

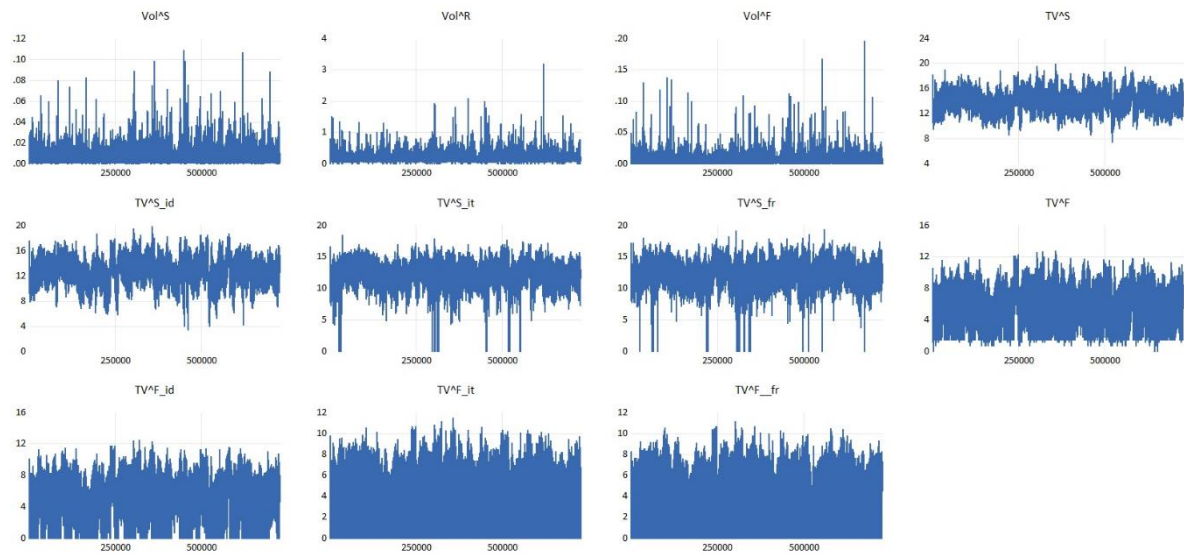


Figure 3 Time-series of Variables (15 Minutes)

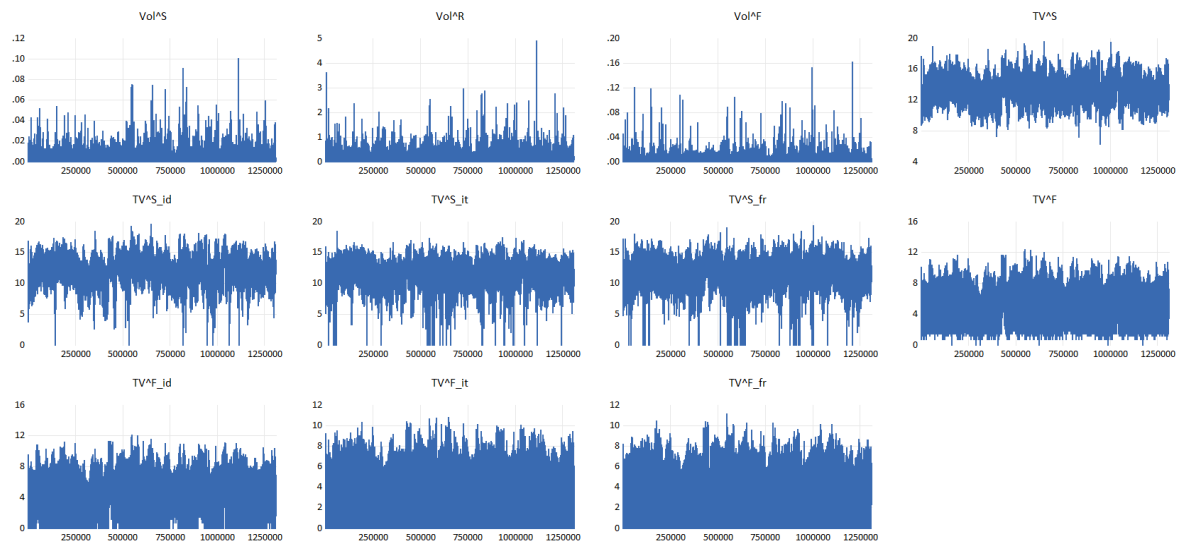


Table 12: Estimation Results of Linear Regression: Samsung Electronics, Vol^S

Regressors		Daily	30 Minutes	15 Minutes
Total Trading Volume	c	-0.03 **	-4.7E-3 ***	-1.7E-3 ***
	TV_{t-1}^S	2.0E-3 ***	4.0E-4 ***	1.9E-4 ***
	TV_{t-1}^F	1.1E-3 ***	2.8E-4 ***	1.6E-4 ***
	SIG^S	1.2E-8 ***	2.7E-9 ***	1.1E-8 ***
	SIG^F	1.4E-5 ***	3.6E-6 ***	2.1E-6 ***
	Adj-R ²	0.34	0.34	0.33
Trading Volume by Investors	c	-0.01	-2.1E-3	-4.3E-4
	$TV_{t-1}^{S,id}$	-1.3E-4	-6.1E-5 ***	-2.5E-5 ***
	$TV_{t-1}^{S,it}$	1.1E-3 **	2.2E-4 ***	1.3E-4 ***
	$TV_{t-1}^{S,fr}$	5.2E-4	8.6E-5 ***	2.5E-5 ***
	$TV_{t-1}^{F,id}$	-1.0E-3 **	1.6E-4 ***	7.2E-5 ***
	$TV_{t-1}^{F,it}$	3.7E-4	-3.0E-5 ***	-9.0E-6 *
	$TV_{t-1}^{F,fr}$	6.7E-4 ***	1.2E-4 ***	7.7E-5 ***
	$SIG^{S,id}$	1.3E-7 ***	7.0E-8 ***	5.6E-8 ***
	$SIG^{S,it}$	2.2E-8 **	2.8E-9 ***	1.4E-8 ***
	$SIG^{S,fr}$	-9.9E-10	1.3E-10	2.1E-9 ***
	$SIG^{F,id}$	2.4E-4 ***	2.9E-5 ***	1.4E-5 ***
	$SIG^{F,it}$	2.8E-5	2.1E-6 *	2.1E-6 ***
	$SIG^{F,fr}$	2.6E-6	9.2E-7 ***	5.6E-7 ***
	Adj-R ²	0.40	0.39	0.36

Note: Estimation results are from the following linear panel regression model:

$$Vol_t = \alpha_t + \sum_{k=1}^K \beta^k TV_{t-1}^k + \sum_{l=1}^L \gamma^l SIG_{t-1}^l + \sum_{t=1}^{T-1} \theta_j D_t + \varepsilon_{it}$$

where, Vol_t is a sample standard deviation of firm i's stock returns at time t, TV_{t-1} is firm i's trading volume, D_t is a time dummy variable. The firm i's stock trading volume variable (TV_{t-1}) is classified by trader types as follows $TV_{t-1}^{S,investor}$, investor={id,it,fr}, where, id is an individual investor, it an institutional investor, and fr a foreign investor. The trading volume of SSF is denoted as $TV_{t-1}^{F,investor}$. $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 13: Estimation Results of Linear Regression: Samsung Electronics, Vol^R

Regressors		Daily	30 Minutes	15 Minutes
Total Trading Volume	c	-0.10 *	1.5E-3	0.03
	TV_{t-1}^S	0.01 ***	0.01 ***	0.01 ***
	TV_{t-1}^F	0.01 ***	4.9E-3 ***	3.9E-3 ***
	SIG^S	6.0E-8 ***	8.0E-8 ***	8.7E-8 ***
	SIG^F	4.5E-5 ***	5.2E-5 ***	6.5E-5 ***
	Adj-R ²	0.69	0.51	0.43
Trading Volume by Investors	c	-0.02	0.05 **	0.08 ***
	$TV_{t-1}^{S,id}$	-3.1E-4	-2.3E-3 ***	-1.8E-3 ***
	$TV_{t-1}^{S,it}$	0.01 ***	4.0E-3 ***	3.9E-3 ***
	$TV_{t-1}^{S,fr}$	2.6E-3 **	1.7E-3 ***	1.7E-3 ***
	$TV_{t-1}^{F,id}$	-3.1E-4	3.3E-3 ***	1.7E-3 ***
	$TV_{t-1}^{F,it}$	-1.4E-3	-9.1E-4 ***	-4.4E-4 ***
	$TV_{t-1}^{F,fr}$	5.0E-3 ***	2.7E-3 ***	2.7E-3 ***
	$SIG^{S,id}$	4.9E-7 ***	1.3E-6 ***	1.5E-6 ***
	$SIG^{S,it}$	1.8E-7 ***	1.8E-7 ***	1.9E-7 ***
	$SIG^{S,fr}$	8.6E-9	1.9E-8 ***	2.8E-8 ***
	$SIG^{F,id}$	3.5E-4 ***	3.2E-4 ***	3.1E-4 ***
	$SIG^{F,it}$	4.0E-5	6.0E-5 ***	8.5E-5 ***
	$SIG^{F,fr}$	2.7E-5 **	1.7E-5 ***	2.1E-5 ***
	Adj-R ²	0.71	0.54	0.47

Note: Estimation results are from the following linear panel regression model:

$$Vol_t = \alpha_t + \sum_{k=1}^K \beta^k TV_{t-1}^k + \sum_{l=1}^L \gamma^l SIG_t^l + \sum_{t=1}^{T-1} \theta_j D_t + \varepsilon_{it}$$

where, Vol_t is a sample standard deviation of firm i 's stock returns at time t , TV_{t-1} is firm i 's trading volume, D_t is a time dummy variable. The firm i 's stock trading volume variable (TV_{t-1}) is classified by trader types as follows $TV_{t-1}^{S,investor}$, investor={id,it,fr}, where, id is an individual investor, it an institutional investor, and fr a foreign investor. The trading volume of SSF is denoted as $TV_{t-1}^{F,investor}$. $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 14: Estimation Results of Linear Regression: Samsung Electronics, Vol^F

		Regressors	Daily	30 Minutes	15 Minutes
Total Trading Volume		c	-0.02	-2.8E-3 **	-6.5E-4
		TV_{t-1}^S	1.7E-3 ***	2.8E-4 ***	1.6E-4 ***
		TV_{t-1}^F	1.2E-3 ***	3.4E-4 ***	2.0E-4 ***
		SIG^S	1.2E-8 ***	2.0E-9 ***	9.4E-10 ***
		SIG^F	1.4E-5 ***	3.7E-6 ***	2.7E-6 ***
		Adj-R ²	0.34	0.38	0.36
Trading Volume by Investors		c	1.3E-4	-7.3E-4	2.6E-4
		$TV_{t-1}^{S,id}$	-4.9E-4	-3.9E-5 **	-9.3E-6
		$TV_{t-1}^{S,it}$	1.0E-3 **	1.5E-4 ***	9.6E-5 ***
		$TV_{t-1}^{S,fr}$	4.6E-4	3.7E-5 *	1.0E-5
		$TV_{t-1}^{F,id}$	-8.3E-4 *	1.8E-4 ***	9.8E-5 ***
		$TV_{t-1}^{F,it}$	3.2E-4	-1.7E-5	-9.6E-6 **
		$TV_{t-1}^{F,fr}$	7.2E-4 ***	1.1E-4 ***	8.4E-5 ***
		$SIG^{S,id}$	2.4E-7 ***	4.6E-8 ***	2.6E-8 ***
		$SIG^{S,it}$	2.9E-9	2.4E-9 ***	6.1E-10 *
		$SIG^{S,fr}$	-2.9E-10	-1.8E-10	6.7E-11
		$SIG^{F,id}$	2.3E-4 ***	4.0E-5 ***	2.4E-5 ***
		$SIG^{F,it}$	1.6E-5	-2.1E-6 *	-3.7E-8
		$SIG^{F,fr}$	2.0E-6	8.4E-7 ***	5.2E-7 ***
		Adj-R ²	0.42	0.43	0.41

Note: Estimation results are from the following linear panel regression model:

$$Vol_t = \alpha_t + \sum_{k=1}^K \beta^k TV_{t-1}^k + \sum_{l=1}^L \gamma^l SIG_t^l + \sum_{t=1}^{T-1} \theta_j D_t + \varepsilon_{it}$$

where, Vol_t is a sample standard deviation of firm i's stock returns at time t, TV_{t-1} is firm i's trading volume, D_t is a time dummy variable. The firm i's stock trading volume variable (TV_{t-1}) is classified by trader types as follows $TV_{t-1}^{S,investor}$, investor={id,it,fr}, where, id is an individual investor, it an institutional investor, and fr a foreign investor. The trading volume of SSF is denoted as $TV_{t-1}^{F,investor}$. $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 15: Estimation Results of Linear Regression: Samsung Electronics, Vol^S

	Regressors	Daily	30 Minutes	15 Minutes
Decom- Posed Trading Volume	c	-0.07 ***	-0.01 ***	-0.01 ***
	E^S	2.8E-3 ***	6.4E-4 ***	4.5E-4 ***
	E^F	0.01 ***	7.7E-4 ***	4.1E-4 ***
	U^S	1.7E-3 ***	1.2E-3 ***	7.6E-4 ***
	U^F	0.01 ***	5.3E-4 ***	2.5E-4 ***
	SIG^S	2.7E-10	2.0E-10	1.0E-9 ***
	SIG^F	-9.3E-6 ***	-9.6E-9	4.5E-8
	Adj-R ²	0.50	0.44	0.41
Decom- Posed Trading Volume by Investors	C	-0.08 ***	-0.01 ***	-4.3E-3 ***
	$E^{S,id}$	1.3E-3 **	-9.8E-5 ***	-4.1E-5 ***
	$E^{S,it}$	1.6E-3 ***	4.1E-4 ***	2.7E-4 ***
	$E^{S,fr}$	4.6E-4	2.5E-4 ***	1.6E-4 ***
	$E^{F,id}$	4.7E-3 ***	6.7E-4 ***	2.8E-4 ***
	$E^{F,it}$	7.8E-4	-8.9E-5 ***	-1.5E-5
	$E^{F,fr}$	1.1E-3 ***	2.5E-4 ***	1.7E-4 ***
	$U^{S,id}$	1.3E-3 ***	2.5E-4 ***	1.3E-4 ***
	$U^{S,it}$	1.6E-3 ***	5.5E-4 ***	3.6E-4 ***
	$U^{S,fr}$	-5.4E-4	3.0E-4 ***	2.1E-4 ***
	$U^{F,id}$	0.01 ***	4.3E-4 ***	1.6E-4 ***
	$U^{F,it}$	-1.3E-4	-1.8E-5	8.1E-6
	$U^{F,fr}$	3.5E-4 **	1.2E-4 ***	8.6E-5 ***
	$SIG^{S,id}$	-1.2E-7 **	2.4E-8 ***	2.3E-8 ***
	$SIG^{S,it}$	1.3E-8	1.4E-9	4.2E-9 ***
	$SIG^{S,fr}$	4.1E-9	-2.2E-11	4.4E-11
	$SIG^{F,id}$	-9.8E-5 ***	2.2E-6	2.3E-6 ***
	$SIG^{F,it}$	8.0E-6	-6.8E-7	-1.8E-6 **
	$SIG^{F,fr}$	-3.4E-7	3.2E-7	1.2E-7
		Adj-R ²	0.52	0.45

Note: Estimation results are from the following linear panel regression model:

$$Vol_t = \alpha_t + \sum_{k=1}^K \beta^k UE_t^k + \sum_{l=1}^L \gamma^l SIG_t^l + \sum_{i=1}^{T-1} \theta_i D_t + \varepsilon_{it}$$

where, Vol_t is range-based volatility of firm i 's stock price at time t , UE_t^k is firm i 's decomposed trading volume. The expected components of trading volume are denoted as E and the unexpected

parts of trading volume U . D_t is a time dummy variable. There are three trader types such as individual investors (id), institutional investors (it), and foreign investors (fr). $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 16: Estimation Results of Linear Regression: Samsung Electronics, Vol^R

	Regressors	Daily	30 Minutes	15 Minutes
Decom- Posed Trading Volume	c	-0.22 ***	-0.08 ***	-0.07 ***
	E^S	0.01 ***	0.01 ***	0.01 ***
	E^F	0.02 ***	0.01 ***	0.01 ***
	U^S	7.9E-4	0.02 ***	0.02 ***
	U^F	0.02 ***	0.01 ***	0.01 ***
	SIG^S	4.1E-8 ***	4.6E-8 ***	6.5E-8 ***
	SIG^F	-9.8E-6	8.4E-6 *	1.5E-5 ***
	Adj-R ²	0.72	0.54	0.46
Decom- Posed Trading Volume by Investors	C	-0.16 ***	-0.05 *	-0.01
	$E^{S,id}$	-0.01 ***	-0.01 ***	-4.4E-3 ***
	$E^{S,it}$	0.01 ***	0.01 ***	0.01 ***
	$E^{S,fr}$	3.1E-3	4.1E-3 ***	4.7E-3 ***
	$E^{F,id}$	0.02 ***	0.01 ***	0.01 ***
	$E^{F,it}$	-2.9E-3	-2.6E-3 ***	-1.1E-3 ***
	$E^{F,fr}$	0.01 ***	0.01 ***	0.01 ***
	$U^{S,id}$	-0.01 ***	-2.7E-3 ***	-2.7E-3 ***
	$U^{S,it}$	0.01 ***	0.01 ***	0.01 ***
	$U^{S,fr}$	-7.5E-4 ***	0.01 ***	0.01 ***
	$U^{F,id}$	0.02 ***	4.2E-3 ***	2.7E-3 ***
	$U^{F,it}$	-1.1E-3	-6.9E-4 ***	-3.3E-4 ***
	$U^{F,fr}$	3.6E-3 ***	2.7E-3 ***	3.2E-3 ***
	$SIG^{S,id}$	9.2E-7 ***	1.0E-6 ***	1.3E-6 ***
	$SIG^{S,it}$	9.1E-8 **	1.3E-7 ***	1.5E-7 ***
	$SIG^{S,fr}$	1.6E-8	1.3E-8 ***	2.5E-8 ***
	$SIG^{F,id}$	-5.1E-4 ***	2.9E-5	6.7E-5 ***
	$SIG^{F,it}$	1.4E-5	3.4E-5	2.8E-5
	$SIG^{F,fr}$	8.8E-6	6.7E-6	7.5E-6
		Adj-R ²	0.74	0.56

Note: Estimation results are from the following linear panel regression model:

$$Vol_t = \alpha_t + \sum_{k=1}^K \beta^k UE_t^k + \sum_{l=1}^L \gamma^l SIG_t^l + \sum_{t=1}^{T-1} \theta_t D_t + \varepsilon_{it}$$

where, Vol_t is range-based volatility of firm i 's stock price at time t , UE_t^k is firm i 's decomposed trading volume. The expected components of trading volume are denoted as E and the unexpected

parts of trading volume U . D_t is a time dummy variable. There are three trader types such as individual investors (id), institutional investors (it), and foreign investors (fr). $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.

Table 17: Estimation Results of Linear Regression: Samsung Electronics, Vol^F

	Regressors	Daily		30 Minutes		15 Minutes	
	c	-0.07	***	-0.01	***	-2.8E-3	***
Decom- Posed	E^S	2.6E-3	***	3.1E-4	***	2.2E-4	***
	E^F	0.01	***	9.4E-4	***	5.5E-4	***
Trading Volume	U^S	2.3E-3	***	4.9E-4	***	3.0E-4	***
	U^F	0.01	***	8.6E-4	***	5.0E-4	***
	SIG^S	-1.8E-9		7.1E-10	***	4.4E-10	***
	SIG^F	-9.9E-6	***	-6.1E-7	***	-4.7E-7	***
	Adj-R ²	0.52		0.47		0.45	
	C	-0.07	***	-0.01	***	-2.3E-3	***
	$E^{S,id}$	8.3E-4		-1.6E-4	***	-7.3E-5	***
	$E^{S,it}$	1.4E-3	**	2.5E-4	***	1.7E-4	***
	$E^{S,fr}$	3.4E-4		1.1E-4	***	7.1E-5	***
	$E^{F,id}$	5.0E-3	***	8.3E-4	***	4.3E-4	***
	$E^{F,it}$	5.9E-4		-5.8E-5	***	-1.7E-5	
Decom- Posed	$E^{F,fr}$	1.3E-3	***	2.5E-4	***	1.9E-4	***
	$U^{S,id}$	1.4E-3	***	3.8E-5	*	3.3E-5	***
Trading Volume	$U^{S,it}$	1.5E-3	***	2.6E-4	***	1.4E-4	***
	$U^{S,fr}$	-5.5E-4		3.9E-5	*	4.7E-5	***
by Investors	$U^{F,id}$	0.01	***	8.1E-4	***	4.1E-4	***
	$U^{F,it}$	-2.7E-4		-9.1E-6		2.2E-5	***
	$U^{F,fr}$	4.7E-4	***	1.3E-4	***	1.0E-4	***
	$SIG^{S,id}$	-1.7E-8		2.8E-8	***	1.6E-8	***
	$SIG^{S,it}$	-4.7E-9		2.2E-9	***	8.1E-10	***
	$SIG^{S,fr}$	4.7E-9		1.6E-10		1.8E-10	**
	$SIG^{F,id}$	-1.0E-4	***	2.8E-6	*	2.3E-6	***
	$SIG^{F,it}$	1.4E-6		-4.7E-6	***	-3.9E-6	***
	$SIG^{F,fr}$	-1.1E-6		2.1E-7		-1.6E-8	
	Adj-R ²	0.54		0.49		0.47	

Note: Estimation results are from the following linear panel regression model:

$$Vol_t = \alpha_t + \sum_{k=1}^K \beta^k UE_t^k + \sum_{l=1}^L \gamma^l SIG_t^l + \sum_{i=1}^{T-1} \theta_i D_t + \varepsilon_{it}$$

where, Vol_t is range-based volatility of firm i 's stock price at time t , UE_t^k is firm i 's decomposed trading volume. The expected components of trading volume are denoted as E and the unexpected

parts of trading volume U . D_t is a time dummy variable. There are three trader types such as individual investors (id), institutional investors (it), and foreign investors (fr). $SIG^{S,investor}$ denotes the degree of opinion dispersion of investors for individual stocks. $SIG^{F,investor}$ the degree of opinion dispersion of investors for SSFs. ***, **, and * imply that the parameter estimate is not zero under a significance level of 0.01, 0.05, and 0.10, respectively.