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Difference in the intraday return-volume relationships of spots and futures: a quantile regression approach

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Abstract
This study examines the difference in the intraday return-volume relationships of spot and index futures. Quantile regression analyses show that the widening effect of the stock trading volume on the distribution of spot returns disappears within a short period of time, whereas that of the futures trading volume remains over the long term. The short-term effect of the stock volume and the long-term effect of the futures volume are both consistent for contemporaneous trading volumes. Furthermore, the futures volume has a significantly positive effect on the option-implied volatility, whereas the stock volume is only associated with the implied volatility of at-the-money options, which can be traded quickly. In contrast, the implied volatility of out-of-the-money options, which are highly speculative, is strongly related to the futures volume. The findings suggest that the stock volume is mainly induced by hedging demand or disagreements of opinion, whereas the futures volume contains information about price movements.

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Keywords Information channel; intraday information content; KOSPI 200 futures; option-implied volatility; return-volume relationship; quantile regression

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1. Introduction

The relationship between asset prices and trading volumes has attracted interest from academics and practitioners for decades, and many theoretical models have been developed and empirical analyses conducted to understand this relationship. The relationship is important because trading activity patterns are useful for understanding financial market efficiency and public and private information revelation processes in securities markets. Theoretical models related to the price-volume relationship include the sequential information model (Copeland, 1976; Jennings & Barry, 1983), the mixture of distributions model (Clark, 1973; Tauchen & Pitts, 1983), the information asymmetry model (Kyle, 1985; He & Wang, 1995), and the heterogeneous opinion model (Harris & Raviv, 1993; Kandel & Pearson, 1995). The related empirical studies investigate topics such as the contemporaneous return-volume relationship (Karpoff, 1987) and the return variance-volume relationship (Epps & Epps, 1976; Lee & Rui, 2002). In addition, recent studies examine dynamic aspects of the return-volume relationship (Chen, Firth, & Rui, 2001; Chuang, Kuan, & Lin, 2009) and its sequential and intraday relationship (Ryu 2015; Webb, Ryu, Ryu, & Han, 2016). Lin (2013) provides good reviews of related studies.

Extensive theoretical and empirical analyses are collectively conducted across many studies, but each of them have some individual limitations. First, although many studies examine Granger non-causality in the conditional mean and/or variance, this property need not hold for other aspects of the model, including the probability distribution. For instance, Diks and Panchenko (2005) point out that Hiemstra and Jones' (1994) test may not accurately test Granger non-causality. Second, when derivatives markets exist, they should be considered as alternative means for trading the underlying assets. Specifically, given that market friction related to shorting assets may cause a negative price-volume relationship, the opportunities provided by derivatives markets to take short positions can affect the price-volume relationship. As mentioned by Kocagil and Shachmurove (1998), if the price-volume relationship in the spot market is affected by market frictions regarding short sales, then derivatives markets, in which taking short positions is less costly (Ryu, 2013; Sim, Ryu, & Yang, 2016), must be taken into account to more clearly and thoroughly analyze the effect of short sale restrictions on the price-volume relationship. Finally, although the relationship between the realized return variance and the trading activity is examined in many related studies (Foucault, Sraer, & Thesmar, 2011; Valenzuela, Zer, Fryzlewicz, & Rheinländer, 2015), the relationship between the option-implied variance, or volatility, and the volume has drawn less attention. Given that the option-implied volatility is an ex-ante expectation of future price fluctuations and is reported to provide information for return forecasting (Giot 2005; Jiang & Tian, 2005; Han, Guo, Ryu, & Webb, 2012; Song, Ryu, & Webb, 2016, 2018), if the trading volume affects the distribution of returns, it should consistently and significantly affect the option-implied volatility as well.

This study investigates the intraday relationship between asset returns and trading volumes in the KOSPI 200 spot and index futures markets, which are liquid and popular financial markets, and tries to fill the gaps mentioned above.[1] First, following Chuang, Kuan, and Lin (2009), we employ Koenker and Bassett's (1978) quantile regression method (QRM) to address the issue regarding the Granger non-causality test. Second, we compare the effects of spot and futures trading volumes on returns to take into account the existence of derivatives markets. Finally, we examine whether the relationship between the spot and futures trading volumes and the option-implied volatility is consistent with the return-volume relationship. The empirical results suggest that the effects of stock and futures trading volumes on spot index returns differ in duration. We find that the trading volumes of spot and futures both widen the distribution of spot returns but that this effect fades within five minutes for the stock market. When we consider contemporaneous trading volumes to control for the temporary price impact, we find strong expansive effects of contemporaneous trading volumes on the distributions of returns in both the spot and futures markets. However, we again observe a reversal in the return-volume relationship in the spot market, whereas the effect persists for over 15 minutes in the futures market. In addition, only the futures trading volume is positively associated with the implied volatility in the options market, although an increase in the trading volume of stocks does lead to an increase in the implied volatility of at-the-money (ATM) options, which have abundant liquidity and the highest spot volatility sensitivity and vega values (Ni, Pan, & Poteshman, 2008; Rourke, 2014) In contrast, the futures trading volume is strongly related to the implied volatility of out-of-the-money (OTM) options, which yield substantial leverage and speculative trading opportunities (Yang, Kutan, & Ryu, 2018; Yang & Ryu, 2018).

Our empirical results are essentially in line with those of previous studies of the return-volume relationship and provide meaningful implications. First, the well-known positive relationship between absolute returns and trading volumes is also found in the context of intraday stock and futures trading. However, the two markets differ, as we observe a short-term relationship for stocks and a long-term relationship for futures. This result implies that active trading in the stock market is more attributable to disagreements regarding asset prices than to information asymmetry among market participants. Thus, these disagreements extend the distribution of returns, but the distribution reverts when the disagreements are resolved. On the contrary, high futures trading volumes precede large spot price fluctuations in the long run, which implies that they are induced by investors with information advantages. This conclusion is supported by the relationship between trading volumes and the option-

[1] We analyze the KOSPI 200 index futures market that is the most representative derivatives in emerging and Asia-pacific financial markets. We also consider the implied volatility constructed from the transactions in the KOSPI 200 options market, one of the most highly liquid and speculative options markets in the world. Section 4 explains why we analyze the futures and options markets and introduce the characteristics and traits of the KOSPI 200 futures and options trading.

implied volatility. Investors trading ATM options, which can be traded quickly, are much more sensitive to stock trading volumes, whereas futures trading volumes are more closely related to the volatility implied by OTM options, which have the advantage of speculative and leverage trading.

The remainder of this paper proceeds as follows. Section 2 reviews the literature related to the price-volume relationship. Section 3 summarizes the quantile regression method used in this study. Section 4 briefly introduce the KOSPI 200 futures and options markets and explain why we focus on these derivatives markets. Section 5 describes the sample data, and Section 6 reports the empirical results. Finally, Section 7 concludes.

2. Literature review

Several classical studies and theoretical models try to explain the relationship between asset prices (or returns) and trading volumes. First, the sequential information model argues that market participants receive information about the value of an asset sequentially, thereby providing an informational advantage to some investors who then trade the asset with less informed investors. Copeland (1976) shows that this information diffusion process generates several temporary equilibria. Jennings, Starks, and Fellingham (1981) extend the model by assuming that risk-averse investors try to maximize their expected utility of wealth. In addition, Jennings and Barry (1983) further extend the model by allowing for speculation by traders in advantageous positions during the information-diffusion process.

Second, the mixture of distributions model relates trading volumes to daily price fluctuations by assuming that price volatility is driven by the number of daily transactions. Clark (1973) argues that the daily price variance is a random variable whose mean is proportional to the mean daily number of transactions, which explains the positive relationship between the trading volume and price volatility. Tauchen and Pitts (1983) use a variance components framework to explain the multiple daily changes in traders' estimations of the fair price, thereby deriving the joint probability distribution of the price and trading volume. This approach has the advantage that the model only depends on a few parameters that can be easily interpreted.

Third, the information asymmetry model is a dynamic trading model in which some market participants are better informed than others (Chung, Park, & Ryu, 2016; Huang & Stoll, 1997; Madhavan, Richardson, & Roomans 1997; Ryu, 2011, 2016, 2017). Kyle (1985) assumes that informed traders intentionally trade gradually to avoid revealing private information too quickly and, thus, gain more profits. Also, Glosten and Milgorm (1985) show that even risk-neutral market makers require a positive reward for liquidity provision if there exist informed traders. He and Wang (1995) propose a multiperiod model with information differences in which investors obtain both public and private information about the fair price of a stock. The investors then trade based on their expected risk-adjusted gains. In this model, high trading volumes caused by exogeneous information are accompanied by price volatility, whereas high trading volumes caused by existing information are not.

Finally, the heterogeneous opinion model differs from the other models, in which investors interpret information identically, because it assumes that a single piece of information can be interpreted differently by different investors (Ahn, Kang, & Ryu, 2008; Ryu, 2015). Harris and Raviv (1993) show that when investors interpret information differently, absolute returns are positively related to trading volumes, consecutive returns are negatively serially correlated, and trading volumes are positively autocorrelated. Kandel and Pearson (1995) propose a model in which agents employ different likelihood functions to interpret information and show that this model yields the observed return-volume relationship in the market.

A strand of the empirical literature investigates the patterns and possible underpinnings of the price-trading volume relationship. Gallant, Rossi, and Tauchen (1992) show that the trading volume and conditional volatility are positively correlated and that high trading volumes tend to follow large price movements. In addition, they find that a large part of the leverage effect is explained by the lagged trading volume and that the risk-return relationship is positive when the lagged volume is considered. Gervais, Kaniel, and Minglegrin (2001) reveal that stocks with unusually high (low) daily or weekly trading volumes tend to increase (decrease) in price during the following month, and they argue that the return premium for stocks with high trading volumes is driven by enhanced visibility, which generates additional demand. Chae (2005) compares trading volumes before scheduled corporate announcements to those before unscheduled announcements to investigate investors' responses to the revelation of private information. The empirical analysis shows that trading volumes decrease before scheduled announcements but not before unscheduled announcements, which implies that trading slows when traders assess that they are on the inferior side of information asymmetry. Yang, Kim, Kim, and Ryu (2018) find that demand shocks decrease stock returns, while supply shocks increase the returns using the structural vector autoregression model. Barber and Odean (2008) test the hypothesis that retail traders tend to, on net, buy stocks that draw attention by being covered in the news, and, therefore, attention-grabbing stocks simultaneously experience high returns and trading volumes. Their empirical analyses on news, trading volumes, and returns suggest that individual investors buy stocks that receive more public attention more aggressively. Banerjee and Kremer (2010) model the relationship between trading volumes and disagreements on the interpretation of public information and conclude that trading volumes and the price volatility are positively correlated when market participants disagree on the interpretation of public news strongly but infrequently.

3. Quantile regressions of trading volumes

Previous studies have consistently argued that trading volumes are closely associated with the volatility rather than the level of returns, although the cause is controversial. Active trading may be a sign of a large negative return, but it can nevertheless be followed by a large positive return. Thus, if the overall market does not shift upward or downward on average, the effects of trading volumes on returns may offset each other, and it can be difficult to pinpoint their relationship. To thoroughly investigate the effect of trading volumes on returns, then, we should examine the relationship between trading volumes and the distribution (e.g., the quantiles) of returns rather than that between trading volumes and the conditional mean of returns.

The conditional mean function of the ordinary least square (OLS) method defines the relationship between the means of the distributions of the dependent and independent variables. This method assumes that the distribution of the dependent variable is not affected by the values of the covariates, which means that the independent variables affect only the central tendency of the dependent variable's conditional distribution and not the scale or shape of the distribution. Hence, when the independent variables are expected to affect the shape of the distribution, a regression method that is robust to changes in the shape of probability distribution is necessary. Koenker and Bassett (1978) therefore devise QRM as an extended version of OLS to address this issue. QRM can be regarded as a generalization of the OLS method to a group of conditional quantile functions, and this setup eliminates estimation bias when estimating the response of a variable with heterogeneous distributions.[2] This methodology, therefore, is effective when the relationship among variables is asymmetric or varies at the tails of the distribution so that it cannot be captured properly by the classical OLS method. Recent studies utilize this property of QRM to analyze the asymmetric return-volatility relationship (Badshah, 2013; Badshah, Frijns, Knif, & Tourani-rad, 2016).

A standard OLS model can be defined as

$$\mathbf{y} = \mathbf{X}^{\mathrm{T}}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \qquad (1)$$

where $\mathbf{y}$, $\mathbf{X}$, $\boldsymbol{\beta}$, and $\boldsymbol{\varepsilon}$ are the dependent variable vector, the independent variable matrix, the coefficient matrix, and a vector of residuals, respectively. In Equation (1), the coefficient vector $\boldsymbol{\beta}$ is normally estimated using a quadratic loss function, that is, given observations $\{\mathbf{y}_i, \mathbf{X}_i\}_{i=1}^{n}$, the estimation is performed by minimizing the following quadratic loss function over $\boldsymbol{\beta}$.

[2] Koenker and Hallock (2001) show that this bias is a major drawback of the OLS method.

$$\sum_{i=1}^{n}\left(\mathbf{y}_i - \mathbf{X}_i^{\mathrm{T}}\boldsymbol{\beta}\right)^2 \tag{2}$$

The OLS method estimates the conditional expectation $\mathrm{E}[\mathbf{y}|\mathbf{X} = \mathbf{x}]$ by minimizing this quadratic loss function. In contrast, median regression, which is the simplest form of QRM, estimates the conditional median of $\mathbf{y}$ given that $\mathbf{X} = \mathbf{x}$ by minimizing the following loss function.

$$\sum_{i=1}^{n}\left|\mathbf{y}_i - \mathbf{X}_i^{\mathrm{T}}\boldsymbol{\beta}\right|. \tag{3}$$

QRM starts from Equation (3) by first defining the quantile loss function ρ_q as

$$\rho_q = \sum_{i=1}^{n}\left[q\mathrm{I}_{[0,\infty)}\left(\mathbf{y}_i - \mathbf{X}_i^{\mathrm{T}}\boldsymbol{\beta}\right)\left|\mathbf{y}_i - \mathbf{X}_i^{\mathrm{T}}\boldsymbol{\beta}\right| - (1-q)\mathrm{I}_{(-\infty,0]}\left(\mathbf{y}_i - \mathbf{X}_i^{\mathrm{T}}\boldsymbol{\beta}\right)\left|\mathbf{y}_i - \mathbf{X}_i^{\mathrm{T}}\boldsymbol{\beta}\right|\right], \tag{4}$$

where the identification function $\mathrm{I}_A(x)$ is defined as

$$\mathrm{I}_A(x) = \begin{cases} 1, & \text{if } x \in \mathrm{A}; \text{and} \\ 0, & \text{otherwise.} \end{cases}$$

Given the definition of ρ_q in (4), we can minimize $\rho_{0.5}$ instead of (3). Similarly, QRM can be conducted for another quantile value by replacing q in ρ_q with the corresponding quantile value.

4. KOSPI 200 spot, futures, and options

The Korean economy has been growing consistently at a remarkable pace, and its financial market becomes a leading emerging market and influential to world-wide securities markets (Ryu, Ryu, & Hwang 2017; Yang, Ryu, & Ryu, 2017). Even after weathering two major financial crises during the last few decades, the Korean economy has been experiencing steady development and growth and was ranked as the world's 11th largest economy in 2017. The Korea Exchange (KRX) has a representative market index, the KOSPI 200, which is a value-weighted index constructed based on the prices of the 200 listed firms with the largest market capitalizations. It also has two representative index derivatives products, the KOSPI 200 futures and options. The KOSPI 200 futures and options market are highly liquid, renowned, and world-class derivatives markets. The high liquidity and active investor participation in these markets are exposed by lower transaction costs and little market friction, measured by bid-ask spreads, market depth, and taxes and other costs. Because of the extremely lower transactions costs in the KOSPI 200 futures and options markets (Lee, Kang, & Ryu, 2015), speculative and professional investors implement their sophisticated trading and enjoy their information edge on the overall market index and economic forecasts by trading the KOSPI 200 futures and options. Therefore, the shocks and news in the spot index markets are instantly followed by the changes in trading and prices in the derivatives markets.

Compared to the developed markets, the KOSPI 200 spot, futures, and options markets have interesting investor participation patterns. While the institutional investors are dominant market players in developed financial markets, both individual investors, who are often driven by sentiments and biases, and domestic and foreign institutional investors, who are relatively sophisticated and often take positions based on economic circumstances, actively participate in the markets. The balanced investor compositions and resultant fast information spillovers and linkages among the markets provide us an ideal setting for addressing the research question in this study.

All of the KOSPI 200 spot, futures, and options markets open at 9:00 at each normal trading day. The spot market closes at 15:00 whereas the derivatives markets extend 15 minutes and close at 15:15. Four contracts with different maturities are available on each trading day for both futures and options. For the futures, the four maturities are the second Thursdays of the next upcoming March, June, September, and December. Option maturities are the second Thursdays of the three consecutive near-term months and the additional next upcoming quarterly month (i.e., March, June, September, or December). Trading activities are concentrated on the futures and options contracts that are closest to maturity; the contracts with longer maturities are rarely traded and exhibit little market liquidity.

5. Sample data

We consider five-minute observations of the KOSPI 200 index, trading volumes of KOSPI200 futures, and the implied volatilities constructed from the KOSPI 200 options prices, from January 3, 2005 to June 30, 2014. All data are collected from the KRX. Futures volumes are measured based on the nearest-maturity contracts. The options-implied volatilities are calculated based on the volume-weighted averages of the implied volatilities of each option contract. We consider the previous findings that the implied volatility dynamics and underlying asset returns are significantly related (Lee & Ryu, 2013), and *ii*) the information contents and properties significantly vary across option moneyness (Ryu, Kagn, & Suh, 2015; Yang, Choi, & Ryu, 2017) in the Korean market. We calculate the options-implied volatilities separately for moneyness groups. The moneyness of a call (put) option is calculated as the ratio of the underlying asset price (strike price) to the strike price (underlying asset price). Options contracts are categorized as out of the money (OTM) if their moneyness values are less than 0.975 and as at-the-money (ATM) if the values are between 0.975 and 1.025. For each intraday sampling interval, we calculate the implied volatilities separately for OTM and ATM options contacts. Only observations for the period between 09:00 and 14:50 each day are considered to prevent any non-synchronous trading effects between the stock and futures markets.

This study utilizes four main variables. First, the percentage return of the KOSPI 200 spot index over each five-minute period, *r*, is employed as the spot return, the main dependent variable. Next, the natural logarithms of the KOSPI 200 spot and futures trading volumes, which are denoted as *lsv* and *lfv*, respectively, are used as the main independent variables. In addition, we include the first difference of the implied volatility of KOSPI 200 index options, *div*, to consider the impact of trading volumes on the return volatility. We use the first difference rather than the level of implied volatility because of its high persistence. Table 1 provides preliminary summary statistics for the main variables. The spot return is close to zero on average over the sample period, and, thus, there is no linear time trend. Both the spot returns and the change in the implied volatility (i.e., *div*), which can be interpreted as the change in the overall option price level, have extremely large kurtosis values. This result implies that intraday returns do not change substantially over such a short period of time. In addition, the trading volumes of index futures are often extreme compared to those of stocks because the spot volume is composed of the trading volumes of various stocks, whereas an index futures contract is a single tradable asset.

Table 1. Summary statistics

		r	*lsv*	*lfv*	*div*
Mean		-0.001	12.394	5.938	-0.033
Median		0.000	12.355	6.080	-0.025
Standard deviation		0.133	0.586	1.122	1.844
Skewness		-0.374	0.375	-1.041	-0.135
Kurtosis		27.984	0.015	2.048	15.073
Percentile	1^{st}	-0.385	11.236	2.303	-5.419
	5^{th}	-0.195	11.504	3.807	-2.740
	25^{th}	-0.053	11.970	5.384	-0.776
	75^{th}	0.054	12.777	6.687	0.722
	95^{th}	0.190	13.423	7.475	2.686
	99^{th}	0.364	13.877	7.965	5.298
Number of observations		164,712	16,4712	164,712	164,712

Note. This table reports summary statistics and percentiles of the spot index return, the stock trading volume, the futures trading volume, and the options-implied volatility. *r* is the percentage return of the KOSPI 200 index. *lsv* and *lfv* are the natural logarithms of the KOSPI 200 spot and futures volumes, respectively. *div* is the first difference of the volume-weighted implied volatility constructed from the KOSPI 200 prices.

6. Empirical findings

6.1 Return-volume relationship

We conduct a set of quantile regressions to investigate the relationship between spot prices and lagged trading volumes. Specifically, we first include the natural logarithms of spot and futures volumes, *lsv* and *lfv*, as separate independent variables:

$$r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=1}^{3}\gamma_i lsv_{t-i} + \varepsilon_t, \qquad (5)$$

$$r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=1}^{3}\gamma_i lfv_{t-i} + \varepsilon_t. \qquad (6)$$

Here, T is the time length of the entire sample period. We include $\frac{t}{T}$ and its squared term in the models to control for the time trend over the sample period. DOP_t is an opening session dummy variable that equals one when *t* is between 09:00 and 10:00 and zero otherwise. DCL_t is a closing session dummy variable that equals to one when *t* is between 13:50 and 14:50 and zero otherwise. Although we do not specifically report them, noticeably many transactions take place one hour after the opening and before the closing in both the spot and futures markets. Thus, dummy variables for these sessions can control for this U-shaped intraday trading volume pattern. Following Chuang, Kuan, and Lin (2009), who show that the squares of lagged returns can weaken the effects of trading volumes on returns, we include the square of lagged index returns as a measure of historical volatility. We can, therefore, investigate the effect of trading volumes on the distribution of returns that cannot be explained by the index return itself.

Since both the spot and futures trading volumes may affect the distribution of returns, we need to compare the relative sizes of their effects. To do so, we include the log ratio of the futures trading volume to the spot trading volume in the model as an independent variable. Thus, the raw trading volume is replaced by the log-ratio of the futures volume to the spot volume, *fs*, to compare the significance of the spot and futures trading volumes:

$$r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=1}^{3}\gamma_i fs_{t-i} + \varepsilon_t. \qquad (7)$$

Table 2 reports the regression results for the relationship between returns and lagged trading volumes. Panels A, B, and C show the results for Equations (5), (6), and (7), respectively. In Panel A, as expected, trading volumes have no significant effect on the median of index returns. However, the coefficient on the trading volume over a five minute period is consistently and significantly negative for return quantiles below the median. Conversely, for return quantiles above the median, this coefficient is estimated to be positive and significant. This result shows that the distribution of returns widens following active trading in the spot market. In short, we confirm the positive effect of the trading volume on the return volatility in intraday trading, as reported by previous studies using daily observations. Over ten-minute periods, however, we do not find a significant return-volume relationship. Thus, the positive effect of the spot volume on the return distribution may persist for only a short time.

As reported in Panel B of Table 2, the coefficients on futures trading volumes over a five-minute period are negative for quantiles below the median and positive for quantiles above the median, which is a similar result to that for spot trading volumes. This finding indicates a positive relationship between the return volatility and futures transactions even though these transactions are not directly linked to the stock index. Thus, the return-volume relationship may be at least partially due to informed trading in addition to the effect of demand pressure. However, the duration of the volume effect differs in the spot and futures markets. Increases in both spot and futures trading volumes lead to an increase in the volatility of returns, but the futures trading volume consistently and significantly widens the distribution of index returns over 10- and 15-minute periods, which is not the case for the spot trading volume. In other words, the volatility of returns fluctuates in the short term after a change in the spot trading volume, whereas the distribution of returns can widen in the long run after a change in the futures trading volume. This result supports the hypothesis that investors with more private information about future market movements may try to exploit this information as much as possible using the leverage effect in the futures market. This explanation is consistent with several previous studies that suggest a role of informed trading in futures markets (Chan, 1992; Min & Najand, 1999; Tse, 1995). Furthermore, the futures trading volume reduces the median of returns in addition to widening the distribution. If the return-volume relationship is induced by informed trading, this result indicates that, on average, informed trading based on bad news is more frequent in the futures market than that based on good news. One possible explanation for this finding is the short sale constraint on stocks because informed traders are likely to take short futures positions as a substitute for selling stocks with large transaction costs. In contrast, buying stocks incurs smaller transaction costs.

Table 2. Relationship between returns and lagged trading volumes

Quantile	*lsv*(*t*-1)	*lsv*(*t*-2)	*lsv*(*t*-3)
Panel A. Spot trading volume			
0.01	-0.0449***	0.0112	-0.0269***
	(-5.92)	(1.26)	(-3.41)
0.05	-0.0238***	-0.0040	-0.0107***
	(-7.13)	(-1.17)	(-3.46)
0.10	-0.0170***	-0.0044	-0.0075***
	(-9.91)	(-2.36)**	(-4.33)
0.25	-0.0087***	-0.0031	-0.0029***
	(-8.18)	(-2.42)**	(-2.61)
0.50	-0.0001	-0.0011	0.0009
	(-0.15)	(-1.27)	(1.09)
0.75	0.0074***	0.0017	0.0041***
	(7.87)	(1.52)	(4.27)
0.90	0.0158***	0.0022	0.0094***
	(9.18)	(1.26)	(5.44)
0.95	0.0177***	0.0044	0.0142***
	(6.13)	(1.49)	(4.53)
0.99	0.0281***	0.0028	0.0240***
	(4.23)	(0.44)	(3.59)
Panel B. Futures trading volume			
0.01	-0.0152***	-0.0086***	-0.0098***
	(-11.68)	(-5.51)	(-6.53)
0.05	-0.0104***	-0.0063***	-0.0058***
	(-19.60)	(-11.46)	(-9.35)
0.10	-0.0077***	-0.0045***	-0.0038***
	(-20.74)	(-11.49)	(-9.10)
0.25	-0.0043***	-0.0020***	-0.0017***
	(-15.91)	(-7.13)	(-6.16)
0.50	-0.0007***	-0.0001	0.0003
	(-3.39)	(-0.62)	(1.44)
0.75	0.0031***	0.0016***	0.0022***
	(11.13)	(5.60)	(8.63)
0.90	0.0068***	0.0028***	0.0046***
	(14.96)	(6.58)	(9.19)
0.95	0.0089***	0.0040***	0.0064***
	(14.26)	(6.78)	(10.67)
0.99	0.0132***	0.0052***	0.0091***
	(11.68)	(3.57)	(6.31)
Panel C. Futures/spot volume ratio			
0.01	-0.0115***	-0.0055***	-0.0060***
	(-8.35)	(-3.29)	(-3.44)
0.05	-0.0078***	-0.0036***	-0.0033***
	(-12.83)	(-4.97)	(-5.05)
0.10	-0.0057***	-0.0025***	-0.0017***
	(-15.45)	(-5.35)	(-4.04)
0.25	-0.0031***	-0.0009***	-0.0006**
	(-12.07)	(-3.68)	(-2.27)
0.50	-0.0007***	-0.0001	0.0002
	(-3.44)	(-0.32)	(1.20)
0.75	0.0019***	0.0006**	0.0011***
	(6.86)	(2.30)	(4.45)
0.90	0.0045***	0.0014***	0.0023***
	(11.43)	(2.94)	(5.41)
0.95	0.0063***	0.0014*	0.0036***
	(11.58)	(1.85)	(5.66)
0.99	0.0102***	0.0011	0.0061***
	(6.70)	(0.63)	(3.71)

Note. This table shows the estimated coefficients, γ_i, of the spot trading volume, futures trading volume, and the ratio of the futures trading volume to the spot trading volume for the following quantile regression models. Panel A: $r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=1}^{3}\gamma_i lsv_{t-i} + \varepsilon_t$; Panel B: $r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=1}^{3}\gamma_i lfv_{t-i} + \varepsilon_t$; Panel C: $r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=1}^{3}\gamma_i fs_{t-i} + \varepsilon_t$. *t*-values are reported in parentheses and estimated using the Markov chain marginal bootstrap method (He & Hu, 2002). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

The ratio of the futures trading volume to the spot trading volume, like the raw futures trading volume, consistently increases the return volatility after five minutes, as shown in Panel C of Table 2. The magnitude and significance of the estimated coefficients are almost similar to those of the futures trading volume. After ten and fifteen minutes, this ratio significantly widens the distribution of returns except for the quantiles above the median. We find no significant effect of the futures volume ratio on the right side of the returns distribution after ten minutes, indicating that informed traders typically prefer futures trading to spot trading but that this preference is not as prominent in the case of good news about index returns. This finding again supports the notion that the short sale constraint can affect the return-volume relationship. On the other hand, the difference in the return-volume relationship for spot and futures volumes is consistent with the findings of Kocagil and Shachmurove (1998), who report bi-directional Granger causality between absolute returns and trading volumes in futures markets. The results show a positive relationship between the futures-spot trading volume ratio and the magnitude of the spot price movement, which means that futures volumes tend to be greater than spot volumes when prices fluctuate more heavily.

As described above, we find that the duration of the return-volume relationship differs for spot and futures trading using a model with lagged transaction volumes. If spot trading increases the volatility of returns only in the short run, this result may be induced by the return-volume relationship within a period shorter than five minutes. Furthermore, during such a short period of time, the liquidity consumed by frequent transactions may be much more important than changes in the distribution of the fundamental asset value. To consider this possibility, we estimate quantile regression models that include the contemporaneous trading volume, as in Equations (8), (9), and (10):

$$r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=0}^{3}\gamma_i lsv_{t-i} + \varepsilon_t, \qquad (8)$$

$$r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=0}^{3}\gamma_i lfv_{t-i} + \varepsilon_t, \qquad (9)$$

$$r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=0}^{3}\gamma_i fs_{t-i} + \varepsilon_t. \qquad (10)$$

Table 3 shows the estimation results for the models including contemporaneous trading volumes. The results show that large volumes tend to appear contemporaneously with large price movements in both the spot and futures markets. However, for lagged trading volumes, the spot and futures volumes differ significantly, as shown above. The coefficients on the lagged spot volume are estimated to be the opposite of those on the contemporaneous volume. Thus, the positive effect of the spot volume on the return volatility may disappear within five minutes, as the returns gradually shift back to their original distribution. This finding implies that the return-volume relationship in the spot market may be attributable to disagreements rather than market information, in line with the finding of Goetzmann and Massa (2005), who show that the dispersion of opinion is positively related to contemporaneous stock trading volumes but negatively related to future returns.

The positive relationship between futures trading volumes and the magnitude of stock index movements, however, persists over time. Therefore, the effect of futures volumes on the distribution of returns is maintained over a long period of time, and at least part of it is related to informed trading rather than the dispersion of opinion or a temporary price impact induced by demand pressure. The results for the futures volume ratio in Panel C of Table 3 also support this trend. The ratio of the contemporaneous futures trading volume consistently widens the distribution of returns, and the futures trading volume ratio in the first five minutes gives the same result. However, as in the case of the lagged trading volume, the coefficients are not significant for quantiles above the median, which implies asymmetry due to the short sale restriction. To summarize, the spot volume only has a short-term effect on the distribution of returns, whereas the effect of the futures volume persists longer even when controlling for contemporaneous trading activities.

Table 3. Relationship between returns and contemporaneous and lagged trading volumes

Quantile	*lsv*(*t*)	*lsv*(*t*-1)	*lsv*(*t*-2)	*lsv*(*t*-3)
Panel A. Spot trading volume				
0.01	-0.1990***	0.0385***	0.0409***	0.0246***
	(-64.91)	(8.63)	(10.60)	(6.22)
0.05	-0.1362***	0.0294***	0.0256***	0.0196***
	(-69.51)	(14.56)	(11.74)	(10.39)
0.10	-0.1010***	0.0210***	0.0182***	0.0159***
	(-66.66)	(13.59)	(11.53)	(11.84)
0.25	-0.0475***	0.0101***	0.0079***	0.0071***
	(-42.91) ***	(9.13)	(7.06)	(7.87)
0.50	-0.0041***	0.0016*	-0.0001	0.0017**
	(-4.90)	(1.90)	(-0.18)	(2.39)
0.75	0.0321***	-0.0055***	-0.0060***	-0.0021**
	(29.77)	(-5.38)	(-6.22)	(-2.17)
0.90	0.0751***	-0.0151***	-0.0147***	-0.0062***
	(54.66)	(-9.55)	(-10.29)	(-4.21)
0.95	0.1051***	-0.0233***	-0.0199***	-0.0099***
	(57.90)	(-9.97)	(-9.37)	(-4.19)
0.99	0.1633***	-0.0327***	-0.0277***	-0.0232***
	(54.34)	(-7.80)	(-6.92)	(-5.57)
Panel B. Futures trading volume				
0.01	-0.0393***	-0.0029**	0.0017	-0.0015
	(-50.90)	(-2.22)	(1.19)	(-1.36)
0.05	-0.0274***	-0.0032***	0.0001	-0.0010
	(-66.94)	(-5.27)	(0.19)	(-1.61)
0.10	-0.0213***	-0.0028***	-0.0003	-0.0005
	(-73.32)	(-7.61)	(-0.76)	(-1.49)
0.25	-0.0118***	-0.0019***	0.0000	0.0000
	(-56.22)	(-8.12)	(-0.16)	(0.07)
0.50	0.0001	-0.0007***	-0.0001	0.0003
	(0.41)	(-3.38)	(-0.68)	(1.36)
0.75	0.0117***	0.0009***	-0.0003	0.0004*
	(53.12)	(3.61)	(-0.94)	(1.84)
0.90	0.0214***	0.0020***	-0.0009**	0.0007*
	(77.89)	(4.85)	(-2.10)	(1.72)
0.95	0.0265***	0.0025***	-0.0008	0.0011**
	(80.47)	(4.00)	(-1.38)	(2.02)
0.99	0.0353***	0.0027**	-0.0016	0.0010
	(45.87)	(2.18)	(-1.21)	(0.83)
Panel C. Futures/spot volume ratio				
0.01	-0.0298***	-0.0018	0.0009	-0.0017
	(-28.76)	(-1.11)	(0.55)	(-1.02)
0.05	-0.0210***	-0.0022***	0.0000	-0.0007
	(-53.02)	(-3.63)	(0.04)	(-1.00)
0.10	-0.0155***	-0.0023***	0.0000	0.0004
	(-49.96)	(-5.55)	(-0.11)	(0.89)
0.25	-0.0080***	-0.0015***	0.0004	0.0003
	(-33.71)	(-5.94)	(1.39)	(0.95)
0.50	0.0004**	-0.0008***	-0.0001	0.0002
	(2.28)	(-3.78)	(-0.59)	(0.99)
0.75	0.0088***	0.0002	-0.0006**	-0.0001
	(41.51)	(0.76)	(-2.48)	(-0.30)
0.90	0.0170***	0.0007	-0.0014***	-0.0003
	(58.03)	(1.56)	(-3.41)	(-0.76)
0.95	0.0219***	0.0014**	-0.0019***	-0.0006
	(55.42)	(1.99)	(-2.86)	(-0.86)
0.99	0.0298***	0.0014	-0.0025*	0.0000
	(33.48)	(0.93)	(-1.81)	(-0.02)

Note. This table shows the estimated coefficients, γ_i, of the spot trading volume, futures trading volume, and the ratio of the futures trading volume to the spot trading volume for the following quantile regression models with the contemporaneous trading volume. Panel A: $r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=0}^{3}\gamma_i lsv_{t-i} + \varepsilon_t$; Panel B: $r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=0}^{3}\gamma_i lfv_{t-i} + \varepsilon_t$; Panel C: $r_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}r_{t-i} + \sum_{i=1}^{3}\beta_{v,i}r_{t-i}^2 + \sum_{i=0}^{3}\gamma_i fs_{t-i} + \varepsilon_t$. *t*-values are reported in parentheses and estimated using the Markov chain marginal bootstrap method (He and Hu, 2002). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

5.2 Impact on implied volatility

The quantile regression estimation results consistently confirm that trading volumes extend the distribution of returns. This result can be interpreted as trading volumes increasing the volatility of returns. However, the return volatility that determines the distribution of future returns is unobservable in practice, and the estimation results depend on the realized returns. Moreover, the absolute value of realized returns may be affected by market microstructure factors, such as the market depth or spreads, in addition to the volatility of returns, and trading volumes are also related to these factors. Therefore, it is necessary to confirm the return-volume relationship using a direct measure of the return volatility. We consider the option-implied volatility, which is the return volatility estimated by investors in the options market. The option-implied volatility is also free from market microstructure issues because it is not directly related to the spot or futures markets. If the trading volume is substantively associated with the return volatility rather than causing temporary effects, it must also have this relationship with the implied volatility in the options market. To examine the relationship between the trading volume and the implied volatility, we conduct similar regressions considering the change in the implied volatility as the dependent variable, as follows:

$$div_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}div_{t-i} + \sum_{i=0}^{3}\gamma_i lsv_{t-i} + \varepsilon_t \quad , \tag{11}$$

$$div_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}div_{t-i} + \sum_{i=0}^{3}\gamma_i lfv_{t-i} + \varepsilon_t \quad , \tag{12}$$

$$div_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}div_{t-i} + \sum_{i=0}^{3}\gamma_i fs_{t-i} + \varepsilon_t \quad , \tag{13}$$

The estimation result using the volume-weighted implied volatility is reported in Panel A of Table 4 and shows that the spot volume cannot predict the return volatility over a five-minute period, whereas the coefficients on the five-minute lagged futures trading volume and the futures volume to spot volume ratio are both estimated to be significantly positive. This result implies that option investors estimate a larger return volatility after an increase in futures trading volumes, which is consistent with the previous quantile regression results. We find no significant relationship between the spot trading volume and the option-implied volatility, which is consistent with this volume's short-term relationship with the distribution of returns.

To more clearly examine the difference in the effects of spot and futures trading volumes on the return volatility, we divide options into two subgroups (i.e., ATM and OTM options) according to the option moneyness (i.e. the ratios of their strike prices to the stock index). For each option moneyness category, we calculate the volume-weighted average of the implied volatilities of individual options. In general, option investors prefer ATM to OTM options for quick trading because ATM options are usually more liquid than OTM options are. In addition, traders in the spot market who want to hedge the unfavourable volatility risk may prefer ATM options because their vega is relatively greater than that of OTM options. On the other hand, OTM options are more advantageous than ATM options for informed trading, which requires waiting for the market to change, because OTM options provide higher leverage than ATM options do. Therefore, the implied volatilities of ATM and OTM options may reflect the views of short-term and informed traders, respectively, in the options market.

Panels B and C of Table 4 show that the implied volatilities of ATM and OTM options have opposite effects. The change in the implied volatility of ATM options is significantly and positively associated with the five-minute lagged spot trading volume but not with the lagged futures trading volume. On the contrary, only the futures trading volume and its ratio to the spot volume are positively related to the change in the implied volatility of OTM options. This result implies that the return-volume relationship over periods of five minutes in the spot market is closely related to ATM options, which are important to investors who want to make quick transactions or hedge a volatility risk in the spot market. However, futures trading, which has a long-term relationship with the volatility of returns, affects OTM options, which are highly related to informed trading. Again, the relationship between trading volumes and the implied volatility supports the hypothesis that the spot trading volume has only a short-term effect, whereas the effect of the futures trading volume on the distribution of returns persists in the long run.

Table 4. Effects of trading volumes on the option-implied volatility

Variable	time t-1	t-2	t-3
Panel A. Volume-weighted implied volatility			
lsv	0.0190	0.0143	-0.0347***
	(1.54)	(1.16)	(-2.88)
lfv	0.0132***	0.0056	-0.0046
	(3.50)	(1.52)	(-1.24)
fs	0.0122***	0.0049	-0.0005
	(3.19)	(1.31)	(-0.13)
Panel B. ATM option-implied volatility			
lsv	0.0262***	-0.0052	-0.0188**
	(3.53)	(-0.71)	(-2.68)
lfv	0.0028	-0.0043**	-0.0057***
	(1.39)	(-2.24)	(-3.02)
fs	-0.0003	-0.0043**	-0.0041**
	(-0.16)	(-2.24)	(-2.22)
Panel C. OTM option-implied volatility			
lsv	0.0126	0.0361**	-0.0415**
	(0.77)	(2.13)	(-2.50)
lfv	0.0289***	0.0152***	-0.0002
	(5.23)	(2.72)	(-0.04)
fs	0.0291***	0.0128**	0.0047
	(5.13)	(2.21)	(0.83)

Note. This table shows the estimated coefficients, γ_i, of the spot trading volume, futures trading volume, and the ratio of the futures trading volume to the spot trading volume for the following quantile regression models for the option-implied volatility. Panel A: $div_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}div_{t-i} + \sum_{i=0}^{3}\gamma_i lsv_{t-i} + \varepsilon_t$; Panel B: $div_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}div_{t-i} + \sum_{i=0}^{3}\gamma_i lfv_{t-i} + \varepsilon_t$; Panel C: $div_t = \alpha + \beta_{tr}\frac{t}{T} + \beta_{trs}(\frac{t}{T})^2 + \beta_{op}DOP_t + \beta_{cl}DCL_t + \sum_{i=1}^{3}\beta_{r,i}div_{t-i} + \sum_{i=0}^{3}\gamma_i fs_{t-i} + \varepsilon_t$. The option-implied volatility is the volume-weighted average of the Black-Scholes implied volatilities of all options (Panel A), ATM options (Panel B), and OTM options (Panel C). t-values are reported in parentheses and estimated using the Newey and West (1987) approach with twelve lags. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

6. Conclusions

This study investigates the intraday relationship between returns and trading volumes of stocks and index futures. We perform quantile regressions of spot returns on the stock and futures trading volumes to identify their relationships. Our empirical results suggest that both stock and futures volumes extend the distribution of spot returns but that these effects persist for different durations. The effect of stock trading volumes on returns disappears within five minutes, whereas futures trading volumes have a significant influence even after fifteen minutes. When we consider contemporaneous trading volumes, the distribution of returns widens due to a large contemporaneous stock volume but returns to its original level in fifteen minutes, whereas the effect of a large futures trading volume remains over time. The finding of a short-term effect of the stock trading volume but a long-term effect of the futures trading volume is supported by the results for the option-implied volatility. Only the futures trading volume is significantly and positively related to the implied volatility in the options market. However, an increase in the stock trading volume precedes an increase in the implied volatility of ATM options, which can be traded quickly and is an effective hedging tool. In contrast, the futures trading volume is closely associated with the implied volatility of OTM options, which offer high leverage and are, therefore, favorable for informed trading. Our findings suggest that the return-volume relationship differs significantly for the stock and futures trading volumes. Specifically, the return-volume relationship for stock trading is mainly attributable to disagreements, whereas futures contracts may be a tool for informed trading.

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