Information flow and trading volumes in foreign exchange markets: The cases of Japan and Korea

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Abstract

We investigate the empirical relationship between trading volumes and spot foreign exchange rates of Korean won (KRW/USD) and Japanese yen (JPY/USD) against the US dollar. We analyze the relationship using two different trading volumes (spot and currency futures) and realized volatility measured by high-frequency (two-minute) data (Andersen, Bollersleve, Diebold and Labys (2003)). It is found for the KRW/USD and the JPY/USD that there is a contemporaneous positive correlation between two trading volumes and volatilities. Such relation, however, does not appear consistently when historical volatility is used as proxy for volatility. Also, empirical results suggest that dynamic relations between volumes and volatility are very different in both foreign exchange markets. The difference in both foreign exchange markets comes either (or both) from under developed hedging markets or from inefficiency in KRW/USD foreign exchange market.

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1. Introduction

The foreign exchange market is the largest and fast-growing financial market with daily turnover in the world. The estimated daily turnover volume in global foreign exchange markets reached $1,500 billion in April 1998, which is more than 100 times as large as trade flows. Yet, exchange rate models have little to say about trading volume, much less the degree to which volume conveys useful information. In traditional macro approach, asset prices adjust every period to make agents content with the specified amount of assets in the portfolios. The adjustment of asset prices instantaneously reflects the arrival of new information in the marketplace, which all participants observe and interpret in the same way. Hence, the basic macroeconomic model of the exchange rate implies all information pertaining to the current and future fundamental determinants of exchange rates.

In addition to the lack of economic models, the unavailability of spot volume data at reasonable high frequencies is a principal handicap for many foreign exchange time-series analyses. Because of the unavailability of data, many previous studies have used foreign currency futures volume. An obvious drawback in these studies is that trading volume in futures is very small compared to OTC volume. Also, two markets are regulated under different trading rules. Therefore, the small trading volume size might be due to either the small number of market participants or the different information contents of volume. The positive relationship between spot and futures volumes may be quite different in their overall behavior. Foreign exchange market turnover growth, for example, slowed down considerably in the late 1980s, while futures turnovers continued to grow vigorously. The other problem is that the choice of futures volume may also induce an omitted-variable problem in the estimation as pointed out by Dumas (1996).

Fortunately, both types of trading volume have been observed in the Korean won and the Japanese yen against US dollar (henceforth KRW/USD and JPY/USD, respectively) exchange market, which allowed us to determine the relevancy of interpretation of the currency futures volume. Most currency spot trading in Korea is done through two foreign exchange brokers and the Korean foreign exchange authority keeps track of the trading volume. The dollar futures trading began with the establishment of Korea

Futures Exchange in April 1998, making data on dollar futures trading volume available for use. The Korean won, not being an internationalized currency, is not traded around the clock, let alone having an offshore market. Therefore, the reported trading volume can be considered to well represent the actual trading volume. Spot trading volume and KRW/USD are available from the Bank of Korea, and currency futures volume is available from the Korea Futures Association. The JPY/USD's spot and currency futures trading volume data are obtained from Datastream . Like brokers in Korea all Japanese foreign exchange brokers should report their JPY/USD trading volume concluded between opening and 3: 30 p.m. (local time) to the Bank of Japan. Currency futures volumes come from Chicago International Monetary Market as in Glassman (1987) and Bessembinder (1994).

The aim of this study is to take the KRW/USD and JPY/USD exchange rates, which are advantageous in terms of data availability, and compare and analyze what effect the spot trading volume and currency futures trading volume have on the volatility of exchange rate. In reality, the existing literature on trading volume is based on vague belief that the currency futures trading volume provides reliable information on the spot trading volume. By using both spot and currency futures trading volumes, we intend to provide the empirical groundwork to see whether the currency futures trading volume can be used as a proxy for spot volume.

The empirical investigation also provides clues on discerning, so called, between 'mixture of distribution' and 'sequential arrival information' hypotheses. Following the work of Clark (1973), the mixture of distribution hypothesis posits a contemporaneous dependence of volatility and volume on an underlying latent event or information flow variable. The sequential information arrival hypothesis, on the contrary, assumes that traders receive new information in a sequential and random fashion, which suggests lagged values of volatility may have the ability to predict current trading volume, and vice versa. Empirical works on contemporaneous correlation and lead-lag relation shed light on discriminating between the two theoretical explanations.

The other contribution to the literature is that we use daily '*realized volatility,*' termed by Andersen, Bollersleve, Diebold and Labys (2001a, b, 2003), by using high frequency data on the KRW/USD and JPY/USD exchange rates and analyze what effect the spot trading volume and currency futures trading volume have on realized volatilities. That is, we treat the exchange rate volatility as observed rather than latent in empirical works. Realized volatility separates itself largely from the volatility estimated by existing time series models, in that it allows observation. It is simple to find realized volatility; for example, daily volatility can be estimated by adding the squares of each returns of minute-unit high frequency data. Using realized volatility, we take both contemporaneous and dynamic relationships into consideration when analyzing the relationship between the spot and currency futures trading volumes and volatility.

A brief summary of the analysis is as follows. The realized volatility of the KRW/USD and JPY/USD exchange rates have a positive relationship with both the spot trading volume and the currency futures trading volume contemporaneously. The currency futures trading volume and the realized volatility of KRW/USD seem to have a feedback relationship. The result of our analysis shows that the effect of a shock from the currency futures trading volume on the realized volatility can last more than ten days. However, there is no clear dynamic relationship between them for JPY/USD. There is uni-directional dynamic relationship from realized volatility to spot trading volume of JPY/USD. Our empirical results are in favor of mixture of distribution hypothesis in the KRW/USD spot foreign exchange market and cannot give clear answer for model selection in the JPY/USD spot foreign exchange market.

This study is organized in the following manner. The next section gives an overview of the existing literature on the relationship between trading volume and volatility, as well as on realized volatility. Section 3 describes the characteristics of the data used including those used to estimate realized volatility. Sections 4 and 5 analyze the contemporaneous and dynamic effects of the spot and currency futures trading on realized volatility. Section 6 concludes with suggestions for future research.

2. Literature Review

A theoretical explanation of the positive relationship between trading volume and volatility is that both variables are both driven by the arrival of new information as in mixture of distribution model, which elaborates on Clark (1983), Epps and Epps (1976), and Tauchen and Pitts (1983). In this model the joint distribution of daily price changes and transaction volume of an asset is derived from a model of intra-day equilibrium price changes and intra-day volume. New information during the day causes traders to update their reservation prices and demand or supply of an asset until the average of their individual reservation prices clear the market again. If they disagree on the interpretation of the new information, then the respective equilibrium price change comes with high transaction volume, while relative unanimity results in a price change with little volume. More formally, market prices P and volume V are modeled as:

$$\Delta P = \sigma_1 \sqrt{I} z_1,$$
$$V = \mu_2 I + \sigma_2 \sqrt{I} z_2,$$

where z_1 and z_2 are independent $N(0,1)$ variables, and I represents the random number of daily equilibria, on account of the new information arriving at the market. The mean μ_2 and the standard deviation σ_2 of intra-day volume are both increasing functions in trader disagreement as measured by the standard deviation of individual trader's reservation price update due to the arrival of new information.

The empirical analysis of trading volume and volatility mostly focuses on the stock market. Studies on the foreign exchange market were limited due to the unavailability the spot trading volume, as mentioned earlier. Of studies using the currency futures trading volume, Baten and Bhar (1993) show that, by using the Japanese yen, currency futures trading volume and volatility have a positive relationship in both the US trading hours and the Asian trading hours. Jorion (1996) finds that implied volatility and currency futures trading volume have a positive relationship in terms of the Deutsche mark. Chatrath et al (1996) have applied the GARCH(1,1) model to five currencies traded at the Chicago Board of Trade, the sterling pound, Deutsche mark, Swiss franc, Canadian dollar, and Japanese yen, and found that the increase in the trading volume increases the volatility of the spot exchange rate.

Hartmann (1998) uses the triennial foreign exchange trading volume reported in BIS survey by combining a large cross-section of exchange rate with volume into a panel. However, the analysis faces the problem of having limited time series information.

Hartmann (1999) uses a new 8-year long daily volume series for the dollar/yen spot market analysis. In Japan, all foreign exchange brokers have to report their trading volume in yen/dollar to the Bank of Japan. Wei (1994) has also used the same data source, but he selected only one daily observation per month to see the relationship between volatility and bid-ask spreads. These data have also some drawbacks; they could be affected by changes in the share of brokered deals in the total trading. Moreover, the broker volume might still be slightly different from the direct inter-dealer volume: dealers tend to turn to brokers for larger transactions because anonymity for larger deals is more important than for smaller ones. Also, since the yen is an internationalized currency traded around 24 hours throughout the world, the data represent a very small fraction of the global yen/dollar market.

Lyons (1995) looks at high-frequency data on actual transactions in the OTC market. The transaction data including information on the direction of order flows was obtained by observing a foreign exchange dealer in New York in one week in 1992. A shortcoming of the research is that it covers only a limited segment of foreign exchange markets and spans a relatively short time period.

Galati (2000) uses what is similar to the data set of this study, daily trading volume for the dollar exchange rates of seven currencies, currencies of Brazil, Colombia, India, Indonesia, Israel, Mexico and South Africa, and finds that in most cases volume and volatility are positively correlated, which is an indication that they both react to unobserved common factors. However, the investigation neither covers the Korean exchange rate market nor analyzes the relationship between trading volume and volatility.

3. Data

The data used to measure realized volatility in this study are two-minute observations of the KRW/USD and JPY/USD spot exchange rates, provided by Delton Asset Management.[1] The sample period is from January 2, 2001 to April 22, 2002. The number of observation days actually used for empirical analysis is 307, excluding weekends, legal holidays, and days in which the exchange rate showed obvious recording errors and in which no observation was made. The number of sample *m*

[1] The data is Reuter screen oneand is available from the website (http://www.dealertown.co.kr).

observed in one day is 180, as the unit of data is two minutes.[2] Therefore, the total data we use are 307 □ 180=55,260 observations.

The daily realized volatility is measured in realized variance, realized standard deviation, and realized log standard deviation, as in Andersen et al (2001a, b, 2003). Let us define the returns of two-minute exchange rate as $(100 \times \Delta \log Y_{180,t})$. The daily realized volatility can be measured by adding the squares of return of 180 observations.[3] In other words, it can be calculated from the two-minute returns of 180·T observations:

$$(realized\ \ volatilty) = real_t \equiv \sum_{j=1,\ldots,180} (100\Delta \log Y_{(180),t-1+j/180})^2$$
$$(realized\ \ standard\ deviation) = std_t = (real_t)^{1/2} \qquad (1)$$
$$(\log realized\ \ standard\ deviation) = lstd_t = \log(std_t) = 1/2 \log(real_t)$$

<Table 1> Correlation Among Three Volatilities

	real		***r2***		***garchv***	
	KRW/USD	***JPY/USD***	***KRW/USD***	***JPY/USD***	***KRW/USD***	***JPY/USD***
Real	1.000	1.000				
r2	0.283	0.264	1.000	1.000		
garchv	0.340	-0.009	0.378	0.053	1.000	1.000

Note: *real*=realized volatility, *r2*= square of return, *garchv*=GARCH.

Table 1 shows the correlation between two very common volatilities—GARCH and a simple square of returns—and realized volatility. In KRW/USD, the correlation coefficients among the three volatility measurements are about 0.3, which is not enough to be judged as low or high. In JPY/USD, the absolute magnitude of the correlations are much smaller than those of KRW/USD. The correlation between realized volatility and historical volatility (*R2*) is 0.26 which size is comparably similar to the number of KRW/USD. However, the one between realized volatility and garch volatility shows

2 A day in this study means six hours, or the hours in which the exchange rate is observed. Although the market opens at 9:30 a.m. and closes at 4:30 p.m., there is a one-hour break, totaling the observation hours to six in one day.

3 A day in this study means six hours, or the hours in which the exchange rate is observed. Although the market opens at 9:30 a.m. and closes at 4:30 p.m., there is a one-hour break, totaling the observation

much different size and opposite sign. Therefore, the simple correlation results indicate that the choice of volatility might potentially cause wrong implications in empirical analysis. As Figure 1 and 2 demonstrate, the two volatility measures, GARCH (*garchv*) and the simple square of returns (*r2*), show similar movements as the realized variance. But, in both currencies, the conditional variances of the GARCH model seem to be too much smoothing when compared to the realized variance. On the contrary, the historical volatility has more erratic movements than realized volatility.

<Table 2> Basic Statistics

	Realized Volatility (real)		***Realized std. (std)***		***Log std. (lstd)***		***Log spot vol. (lsvol)***		***Log future vol. (lfvol)***	
	KRW	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***
Mean	0.1502	0.2535	0.3345	0.4530	-1.2493	-0.8786	7.8917	6.19E-16	5.7130	1.95E-15
Median	0.0770	0.1422	0.2775	0.3771	-1.2818	-0.9752	7.9001	0.0018	5.7186	-0.0458
Max.	1.0425	1.6079	1.0210	1.2680	0.0208	0.2375	8.3847	0.7588	6.9178	3.7749
Min.	0.0045	0.0385	0.0673	0.1964	-2.6984	-1.6276	7.1263	-0.8238	4.7331	-2.8926
Std. Dev.	0.1872	0.2979	0.1961	0.2202	0.5540	0.3910	0.2108	0.2675	0.4276	1.1231
Skewness	2.3286	2.6673	1.2921	1.9059	0.1225	1.0579	-0.5806	-0.2703	-0.0491	0.2123
Kurtosis	8.5900	9.8857	4.2634	6.1654	2.5193	3.6112	3.9936	3.4316	2.7642	3.3256
Jarcque -Bera	677.16 (0.000)	663.86 (0.000)	105.84 (0.000)	214.81 (0.000)	3.7236 (0.155)	42.438 (0.000)	29.882 (0.000)	4.1904 (0.123)	0.8344 (0.658)	2.3972 (0.302)

The basic statistics for information variables are described in Table 2. Trading volumes are measured in million USD and transformed with logarithm commonly used in the previous literature. Two exchange rates have slightly different features in the basic statistics. In KRW/USD, among three volatility measures, logarithmic standard deviation of realized volatility (*lstd*) does not display excess kurtosis and is, though, slightly skewed to the right. We cannot reject the null hypothesis of normality, based on the Jarque-Bera test, of *lstd*. In JPY/USD, on the contrary, all volatility measures do not have normal distribution. We cannot reject normality of currency futures trading volume of both exchange rates and spot trading volume of JPY/USD. One notable thing is that spot trading volumes of both exchange rates are slightly skewd to the left except

hours to six in one day.

JPY/USD’s currency futures trading volume. Table 3 shows unit root test results. We cannot reject the hypothesis of no unit root of *lstd* and the two trading volumes of KRW/USD and JPY/USD.

<Table 3> Unit Root Test

	real		***std***		***lstd***		***lr2***		***lsvol***		***lfvol***		***Critical value (1%)***	
	KRW	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***
ADF	-7.83	-6.092	-6.330	-5.978	-4.918	-5.759	-5.872	-4.615	-3.987	-6.165	-5.204	-4.272	-3.453	-3.463
PP	-12.03	-13.84	-11.48	-13.39	-10.44	-12.89	-14.97	-15.70	-9.594	-11.42	-10.00	-12.63	-3.453	-3.463

4. Volume and Volatility: Contemporaneous Relationship

In this section, we analyze the contemporaneous relationship between foreign exchange trading volume and exchange rate volatility of KRW/USD and JPY/USD. For robust check and comparison reason, we additionally take into consideration the logarithmic realized standard deviation together with the square of returns of both exchange rates.

Table 4 shows the correlation coefficients between information variables. We incorporate JPY/USD exchange rate into our empirical analysis, since it has been argued in the previous literature[6] that there are strong co-movements between the KRW/USD volatility and that of JPY/USD.[7] Some conspicuous results can be summarized as follows. First, in both exchange rates, the correlations between trading volumes and volatility are more outstanding in the case of currency futures trading volume than spot trading volume, though the magnitude of the correlation is different in each exchange rate. In KRW/USD (JPY/USD), the correlation coefficient between currency futures trading volume and realized volatility is 0.44 (0.153), whereas that between spot trading volume and realized volatility is relatively (slightly) lower, or 0.14 (0.147). Both exchange rates records similar, in absolute magnitude, size between *lstd*

6 See Chung and Joo (1999).

7 JPY/USD’s volatility is measured by the square of returns.

and spot trading volume. Second, the KRW/USD volatility, either *lstd* or *lr2*, as expected, has a positive correlation with the JPY/USD volatility (*lydr2*). Further, while the correlation coefficient between currency futures trading volume and JPY/USD volatility is about 0.1, there is no correlation between spot trading volume and yen-dollar volatility. The correlation analysis invites a question of whether currency futures trading volume is a more appropriate variable conveying information of both domestic and overseas foreign exchange markets than spot trading volume.

<Table 4> Correlation between Information Variables

	lstd		***lr2***		***lydr2***		***lsvol***		***lfvol***	
	KRW	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***
lstd	1.0000	1.0000								
lr2	0.3637	0.1672	1.0000	1.0000						
lydr2	0.1939		0.1767		1.0000	1.0000				
lsvol	0.1442	0.1478	0.1456	0.0718	-0.0142		1.0000	1.0000		
lfvol.	0.4432	0.1534	0.2879	0.1601	0.0981		0.3130	0.0707	1.0000	1.0000

Note: *lstd*=(realized volatility), *lr2*=(square of returns), *lydr2*=(square of returns of yen/dollar), *lsvol*=(spot volume), *lfvol*=(currency futures volume).

To find a deeper relationship than just the simple correlation, if exists, between trading volume and volatility in KRW/USD and JPY/USD foreign exchange marekts, we estimate an empirical relationship specified with the following equation (2):

$$volatility_t = \beta_0 + \sum_{i=1}^{m} \beta_i \; volatility_{t-i} + \delta\left[volume_t\right] + \varepsilon_t \qquad (2)$$

where '*volatility*' either stands for realized volatility (*lstd*) or simple square of returns (*lr2*), and '*volume*' means logarithmic spot trading volume (*lsvol*) or logarithmic currency futures trading volume (*lfvol*). We include the lagged variables to take into consideration the presence of serial correlation in volatility; trading volumes in the same period are used as an explanatory variable to examine the contemporaneous relationship.

<Table 5> Empirical Results for Contemporaneous Relationship

	β_0		$\beta 1$		β_2		δ_{lsvol}		δ_{lfvol}		R^2	
	KRW	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***
lstd	-3.732 (-3.76)	-0.812 (-11.8)	0.379 (6.842)	0.077 (1.075)	0.212 (3.851)		0.407 (3.245)	0.197 (1.870)			0.296	0.031
	-2.741 (-6.72)	-0.768 (-11.1)	0.310 (5.601)	0.127 (1.784)	0.156 (2.889)				0.362 (5.523)	0.053 (2.139)	0.339	0.038
lr2	-12.79 (-2.89)	-2.244 (-10.8)	0.127 (2.169)	-0.103 (-1.46)	0.078 (1.342)		1.314 (2.351)	0.366 (0.621)			0.044	0.011
	-9.777 (-5.64)	-2.186 (-10.4)	0.070 (1.188)	-0.086 (-1.19)	0.045 (0.781)				1.240 (4.303)	0.277 (2.041)	0.085	0.029

Notes: (1) Two lags based on BIC.
(2) Values in parenthesis are *t*-values.

Empirical results for equation (2) are summarized in Table 5. In KRW/USD, both spot trading volume and currency futures trading volume increase the current volatility. The hypothesis that trading volume does not affect volatilities is rejected at one percent significant level, regardless of either choice of volatility or trading volume. The same analysis of JPY/USD share a common feature of positive relation between two trading volumes and volatilities all but the coefficient of JPY/USD spot trading volume is not significantly different from zero. The coefficient of determination is high when realized volatility is used as dependent variable in both exchange rates..

To check robustness or avoid possible wrong interpretation due to misspecification, we additionally test the following equation of (3-1) for KRW/USD and (3-2) for JPY/USD.

KRW/USD case:

$$volatility_t = \beta_0 + \sum_{i=1}^{m} \beta_i \, volatility_{t-i} + \delta \, volume_t + \gamma \, lydr2_t + \lambda_1 r_t + \lambda_2 r_t I_t + \varepsilon_t \qquad (3\text{-}1)$$

JPY/USD case:

$$volatility_t = \beta_0 + \sum_{i=1}^{m} \beta_i \, volatility_{t-i} + \delta \, volume_t + \lambda_1 r_t + \lambda_2 r_t I_t + \varepsilon_t \qquad (3\text{-}2)$$

where *lydr2* the square of returns of JPY/USD, and r_t stand for and returns (or log difference) of each exchange rate. For KRW/USD, we include one more variable of JPY/USD volatility to reflect, if exists, the effect of JPY/USD, an international currency , on KRW/USD volatility. The notation I_t denotes an indicator function with one when each exchange rate depreciates and zero otherwise.

We specify equation (3-1) based on empirical findings of literature such as Chung and Joo (1999). They argue two things: first, there is a strong co-movement between volatilities of KRW/USD and JPY/USD. If JPY/USD's volatility commonly affects trading volume and volatility of KRW/USD, then the contemporaneous correlation between the two variables of KRW/USD would be spurious. Second, there is asymmetry in KRW/USD's volatility. That is, volatility of the depreciation period is different from that of appreciation. Thereby, equation (3-1) would allow us to avoid misspecification in the volatility process.

<Table 6> Contemporaneous Relationship with Asymmetry in Volatility

	δ_{lsvvol}		δ_{lfvol}		γ		λ_1		λ_2		$\lambda_1+\lambda_2$		R^2	
	KRW	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***	***KRW***	***JPY***
lstd	0.330 (2.75)	0.189 (1.83)			0.027 (2.34)		-0.410 (-3.6)	-19.07 (-3.1)	0.883 (4.77)	34.67 (3.36)	0.470 (19.8)	15.60 (4.64)	0.372	0.083
			0.275 (4.12)	0.040 (1.60)	0.025 (2.21)		-0.340 (-3.0)	-18.47 (-2.9)	0.764 (4.11)	31.91 (2.94)	0.424 (16.1)	13.43 (4.41)	0.392	0.083
lr2	0.330 (1.05)	0.203 (0.57)			0.010 (0.33)		-6.211 (-21)	-314.4 (-15)	12.15 (25.2)	666.8 (19.0)	5.943 (469)	352.4 (92.6)	0.713	0.651
			0.070 (0.41)	-0.019 (-0.2)	0.008 (0.26)		-6.216 (-20)	-312.4 (-14)	12.16 (24.4)	664.8 (18.2)	5.950 (452)	352.3 (87.1)	0.712	0.67

Note: (1) Estimation results $\beta's$ are not reported here.
(2) Values in parenthesis are *t*-values except for $\lambda_1+\lambda_2$, where *F*-values of the null hypothesis of $\lambda_1+\lambda_2=0$.

$\lambda_1+\lambda_2=0$.

Table 6 reports the results from equation (3-1, 2). The results display some variations across specifications, but the qualitative conclusions appear robust. In both KRW/USD and JPY/USD, there is asymmetry in volatility as found in the previous literature: each exchange rate's depreciation results in larger volatility bursts than do the currency's appreciation of the same magnitude. Also, empirical results suggest that the volatility of KRW/USD increases, as does that of JPY/USD. The asymmetry and the Japanese yen's volatility influence only apply to realized volatility. One notable thing is that the contemporaneous relationship ,commonly in both exchange rates, disappears with the square of returns. Therefore, realized volatility is a more useful and appropriate measure for investigating volume-volatility relationship.

To summarize, the empirical results in this section indicate a positive contemporaneous dependence between volatility and the two trading volumes. We now turn to the dynamic relationship of volatility and trading volume.

5. Volume and Volatility: Dynamic Relationship

In this section, we investigate the dynamic relationship between trading volume and volatility. Hence, a main question is to find, if exists, a lead and lag or feedback relationship or to have mutually explanatory power with some lags between the two variables. There are many ways to analyze inter-relationships between the two variables. One simple but useful empirical methodology to uncover and compare inter-relationships among the three variables is the Granger causality test and impulse response function (IRF) that are byproducts of vector auto-regression (VAR) estimation. The Granger causality tests provide information on causal or explanatory relationships between two variables. The impulse response function shows the response of each variable to the structural shock.

<Table 7> Result of Granger Causality Test

Spot Volume → Futures Volume				**Futures Volume → Spot Volume**			
KRW/USD		*JPY/USD*		*KRW/USD*		*JPY/USD*	
0.733		0.631		0.254		0.030	
Spot Volume → Volatility				**Volatility → Spot Volume**			
lstd		***lr2***		***lstd***		***lr2***	
KRW/USD	*JPY/USD*	*KRW/USD*	JPY/USD	*KRW/USD*	*JPY/USD*	*KRW/USD*	*JPY/USD*
0.547	0.772	0.517	0.725	0.0003	0.101	0.822	0.043
Futures Volume → Volatility				**Volatility → Futures Volume**			
lstd		***lr2***		***lstd***		***lr2***	
KRW/USD	*JPY/USD*	*KRW/USD*	*JPY/USD*	*KRW/USD*	*JPY/USD*	*KRW/USD*	*JPY/USD*
0.000	0.779	0.010	0.400	0.057	0.631	0.105	0.636

Note: Numbers are *p*-values of the null hypothesis of no Granger causality .

Table 7 summarizes the Granger causality tests between volume and volatility.[8] The results can be summarized by the following three points. First, in KRW/USD, there is no causal relation between currency futures trading volume and spot trading volume in any direction. In JPY/USD, there is, however, one uni-directional causal relation between them: currency futures trading volume Granger cause spot trading volume. Second, there is no clear causal relationship between spot trading volume and exchange rate volatility of KRW/USD, apart from the fact that the relationship in which realized volatility of KRW/USD appears weakly to be useful for forecasting future values of spot trading volume of KRW/USD. Interestingly, in JPY/USD, volatility, both *lstd* and *lr2*, strongly Granger causes spot trading volume, though the degree of causality is much more strong with *lstd* than with *lr2*. Third, we cannot reject of the null hypothesis that currency future volume does not Granger cause volatility of KRW/USD but the reverse relationship is not true. When realized volatility is replaced with a simple square of returns, exchange rate volatility precedes weakly (in the statistical sense), but there is

8 In the VAR analysis, we set VAR lags to two based on BIC. Empirical results for dynamic relation are based on VAR(2).

a clear relationship in which currency futures trading volume precedes realized volatility. However, there is no a causal relationship between currency futures trading volume and exchange rate volatility, regardless of choice of volatility, in both directions for JPY/USD.

Now let us look at the dynamic relationship between trading volume and exchange rate volatility through impulse response analysis. Figures 3 through 6 show the impulse response functions of KRW/USD foreign exchange market along with asymptotic two standard deviation errors.[9] To check the sensitivity of results to the imposed ordering, we take into consideration eight pairs of volume and volatility.[10] Figure 2 shows the impulse response functions of currency futures volume and realized volatility to two structural shocks: the top panel is for (volume, volatility) ordering and the bottom panel is for the reversed ordering. From Figure 3, we can easily see that there is a feedback relationship between currency futures trading volume and realized volatility, as the shock from each variable has a spillover effect on the other variable in a positive direction. This result is not affected by the ordering of VAR variables. In response to the volume shock, volatility initially increases and then gradually drops to zero after about ten days. In response to the volatility shock, futures volume increases for two or three days and then gradually drops to zero after about seven days, which is clearer with (volatility, volume) ordering.

Figure 4 shows the impulse response functions of realized volatility and spot trading volume. Responses of the two variables to shocks are not sensitive to the ordering of variables. Spot volume does not respond to volatility shock. In response to volatility shock, spot volume initially increases but then drops quickly to zero after one day. Figure 5, illustrating the result of the impulse response function using currency futures trading volume and the variable defined by square of returns, may seem similar to features of figure 3 of with realized volatility, but the feedback effect is somewhat irregular and duration is short when compared to the case using realized volatility. In Figure 6, where spot trading volume and square of returns are used to define volatility, the analytical result is similar to that of Figure 4, that is, with no clear spillover effect found in both directions.

9 Standard errors are calculated from the Monte Carlo simulation of standard 100 runs.

For the impulse response analysis of JPY/USD, the results are dramatically different from the KRW/USD case. Impulse responses of the case of JPY/USD are depicted in figures 6 thru 9. There is no clear dynamic relationship between volume and volatility except between spot trading volume and realized volatility. In response to the realized volatility shock, spot trading volume has clear response regardless of variable ordering.. After two days, the response of the spot volume reaches peak and then sharply drops to zero after three days. When the realized volatility is replaced with simple squre of JPY/USD's returns, the dynamic relation does not hold. Currency futures volume and volatility do not exhibit any feedback relationship, which is very different from the case of KRW/USD.

In sum, the dynamic relationship between trading volume and volatility very much depend on the choice of volume, volatility and exchange rate. From the dynamic relationship analysis of KRW/USD, we can see that currency futures trading volume and volatility have feedback effects upon each other even though the feedback effects are weak with spot trading volume. When comparing this result with that of the contemporaneous correlation analysis, we find no clear pattern of a dynamic relationship between spot trading volume and exchange rate volatility in both directions, by which we cautiously argue that the effect of spot trading volume on exchange rate volatility is limited to the contemporaneous relationship. For JPY/USD, spot trading volume and volatility have contemporaneous relationship as well as dynamic one from volatility to spot trading volume. The dynamic relationship does not hold when realized volatility is replaced with a simple square of returns of JPY/USD exchange rate that is commonly used in previous literature. In KRW/USD foreign exchange market, currency futures trading volume has both contemporaneous and dynamic explanatory powers with regard to exchange rate volatility. However, there is no any dynamic relationship between currency future trading volume and volatility of JPY/USD.

In sum, the currency futures trading volume in Korea seems to, despite its small size, convey additional information flows to spot volume in the Korean foreign exchange market. The presence of the feedback effect suggests that the information flowed into the currency futures market is not immediately absorbed by the price variable (exchange

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10 Eight pairs come from two volumes and two volatilities with changing orders.

rate) and needs a considerably time, ten days, say, before being reflected in the market. Such a result adds persuasive weight to the mixture of distribution hypothesis for the spot KRW/USD foreign exchange market. On the other hand, currency future markets for KRW/USD would be more appropriately delineated, if needed, with a sequential information arrival model, as argued by Copeland (1976), where information spreads sequentially to other market participants. The result of JPY/USD might be easily interpreted: the increase in volatility of JPY/USD may raise the demand of hedging instruments that results in higher transactions of JPY/USD spot. The appropriate market microstructure model for JPY/USD is not clear. The model should incorporate not only contemporaneous relationship between volume and volatility as well as have information (or news arrival) variable that initially influence only on volatility.

6. Conclusion

This article investigates the empirical relationship between trading volume and spot Korean won and Japanese yen against US dollar exchange rate (KRW/USD and JPY/USD, respectively). We analyze the relationship using two different trading volumes—spot and currency futures—and the *realized volatility* measured by high-frequency (two-minute) data. Empirical results suggest there is a contemporaneously positive correlation between the two trading volumes and volatility. The realized volatilities of KRW/USD and JPY/USD exchange rates have positive relationship with both the spot trading volume and currency futures trading volume contemporaneously. In both exchange rates, such a relationship, however, does not appear consistently when square returns are used as a proxy for volatility. To check the robustness of the result, we estimate various specifications such as volatility asymmetry. We confirm the result and find volatility of depreciation period is much higher than that of appreciation. Two exchange rates show dynamically different volume and volatility relationship. That is, the two volumes have dynamically different information content on volatility. There is a clear lead-lag relationship between currency futures trading volume and volatility of KRW/USD, which is not the case with spot trading volume and with JPY/USD. For KRW/USD, the currency futures trading volume, unlike the spot trading volume has a feedback relationship with realized volatility. The effect of the shock of currency futures trading volume on realized volatility of KRW/USD last ten or more days. Therefore, despite the fact that the currency futures trading volume is smaller than the spot trading volume in Korea, it is considered a highly useful variable that faithfully reflects the flow of new information moving into the foreign exchange market. For JPY/USD, we find only dynamically uni-directional relationship lasting two days from realized volatility to spot trading volume. Therefore, the empirical result of JPY/USD, along with contemporaneous relationship between spot trading volume and realized volatility, can be interpreted as following. When new information arrives in foreign exchange market, the variable affects commonly on both spot volume and volatility. The uncertainty, as measured by volatility, incurs hedging demand such as options or forward but not currency futures, which results in increasing in spot trading volume.

As such, our study is supportive of the mixture of distribution hypothesis in the KRW/USD spot foreign exchange market. Also, currency futures volume conveys additional information regarding price formation, despite its relatively small size. For JPY/USD, theoretical model should not only contain contemporaneous relationship between spot trading volume and volatility but also contain information variable that affects asymmetrically on them in dynamic way. One clear caveat in our empirical results emphasize that a better characterization of return volatility is needed to test theoretical explanations such as the mixture of distribution or sequential information hypothesis.

In policy perspective, the difference in both foreign exchange markets comes either (or both) from under developed hedging markets or from market inefficiency in KRW/USD foreign exchange market. On the contrary, JPY/USD currency is internationalized one and is trading around 24 hours a day. We believe that it is impossible information in the market disseminate at very slow pace, which allow arbitrage profit. It is intriguing question why there exists the feedback relationship between the currency futures trading volume and volatility last over a considerable span of time. A detailed study is necessary to verify the exact source of prolonged dynamic relationship between them.

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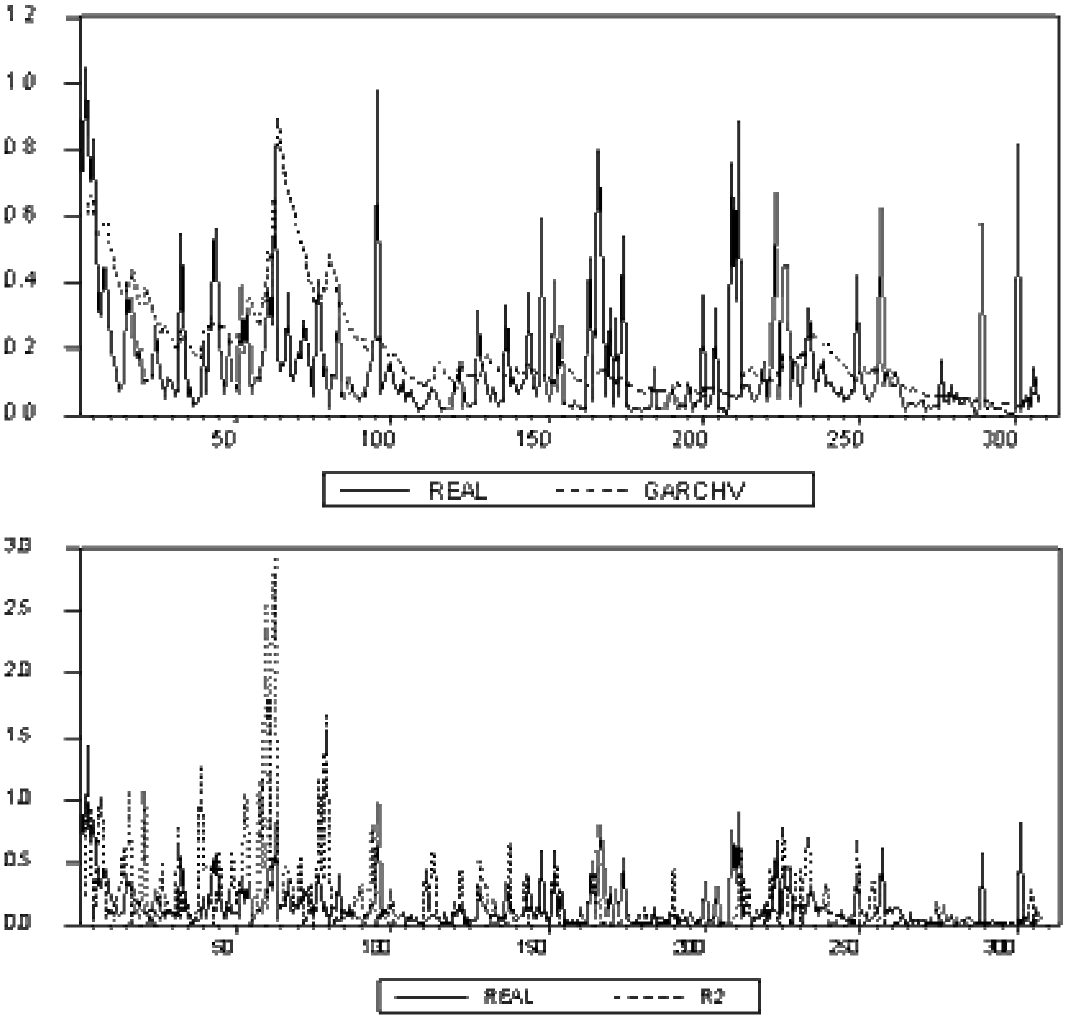
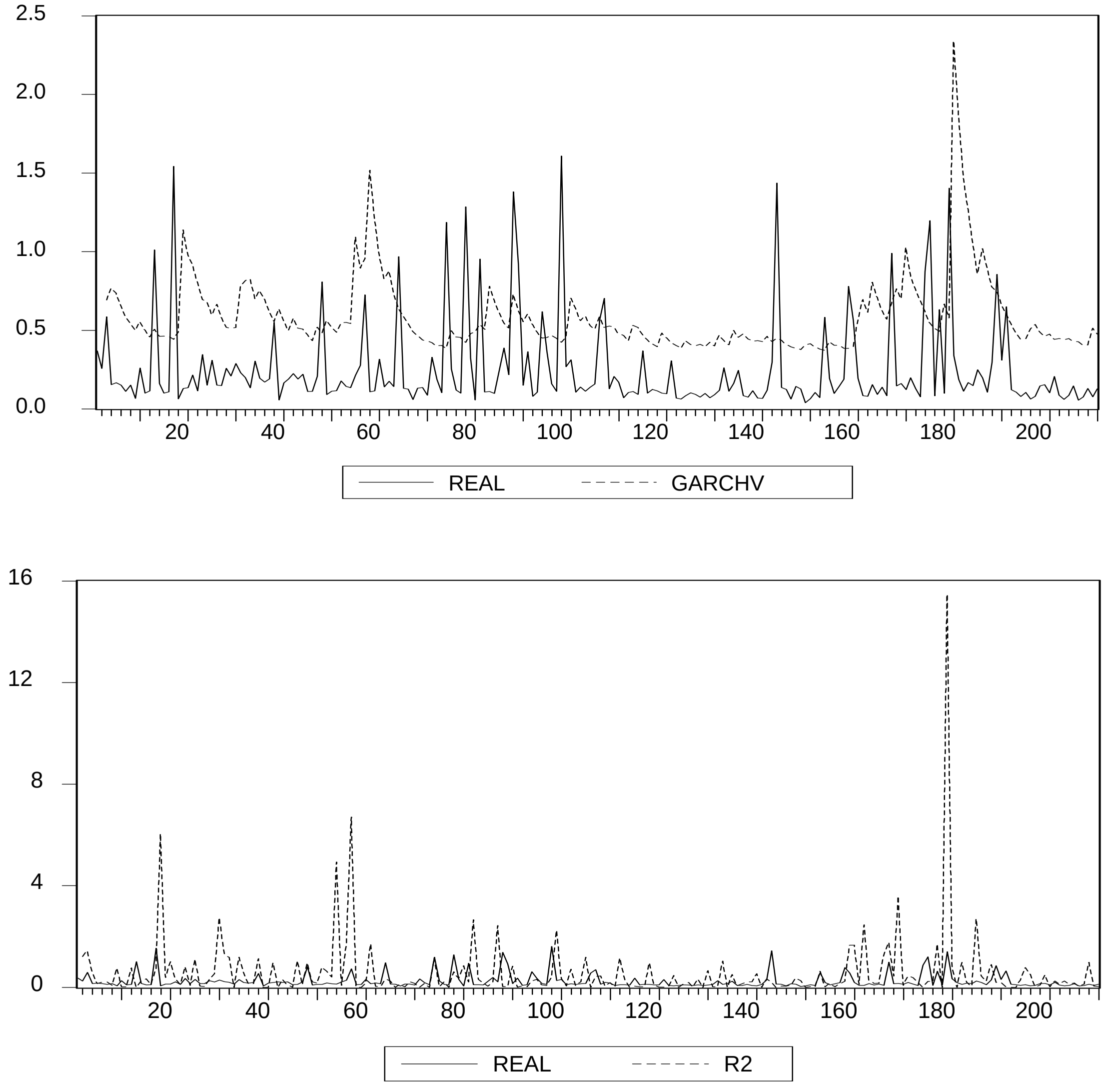
<Figure 1> Realized Volatility and Other Measures of Volatility(KRW/USD)



Note: The term “real”, “GARCHV”, and “R2” stand for realized volatility, GARCH, and square of returns, respectively.

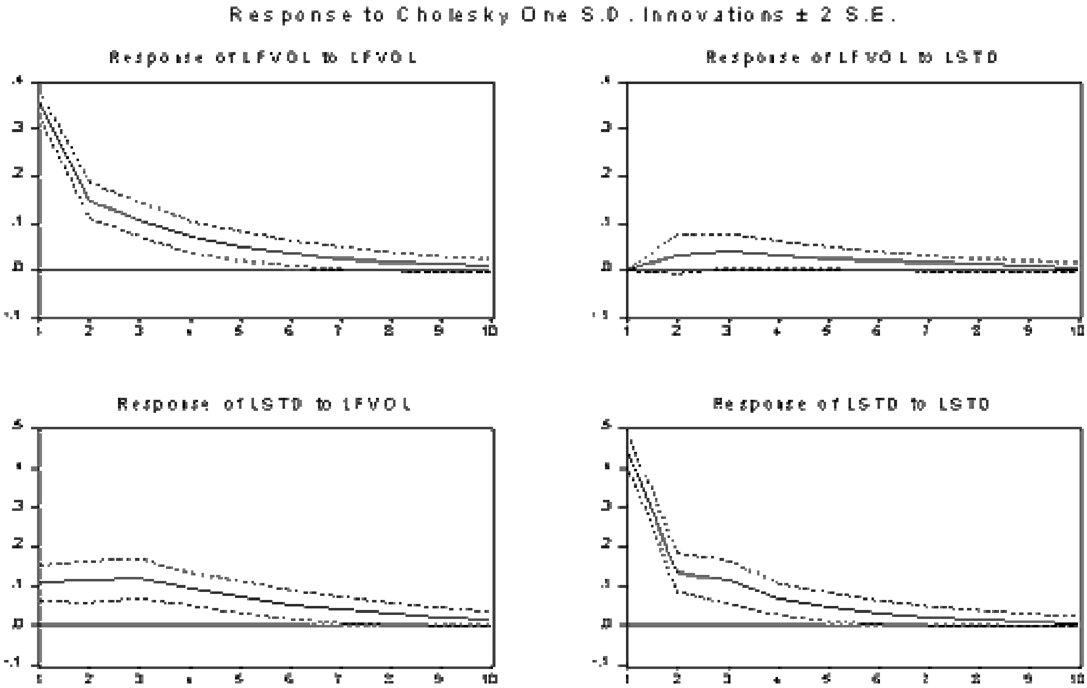
<Figure 2> Realized Volatility and Other Measures of Volatility (JPY/USD)



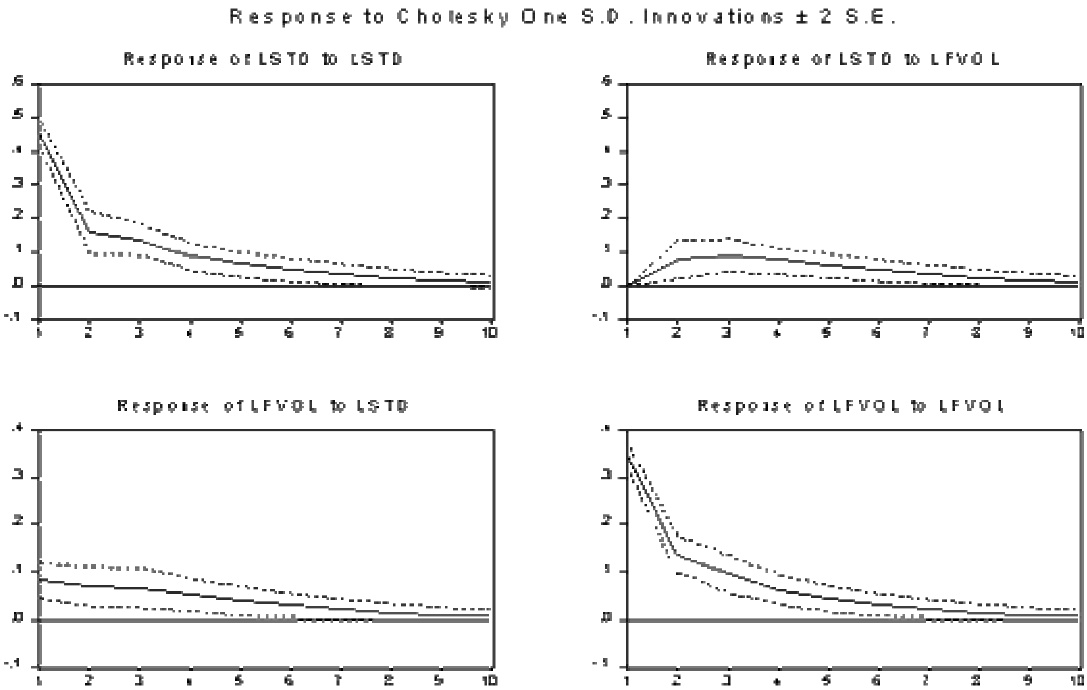
Note: The term “real”, “GARCHV”, and “R2” stand for realized volatility, GARCH, and square of returns, respectively.

<Figure 3> Impulse Response Function with Realized Volatility (KRW/USD)

(a) Ordering: (futures volume (*LFVOL*), realized volatility (*LSTD*))

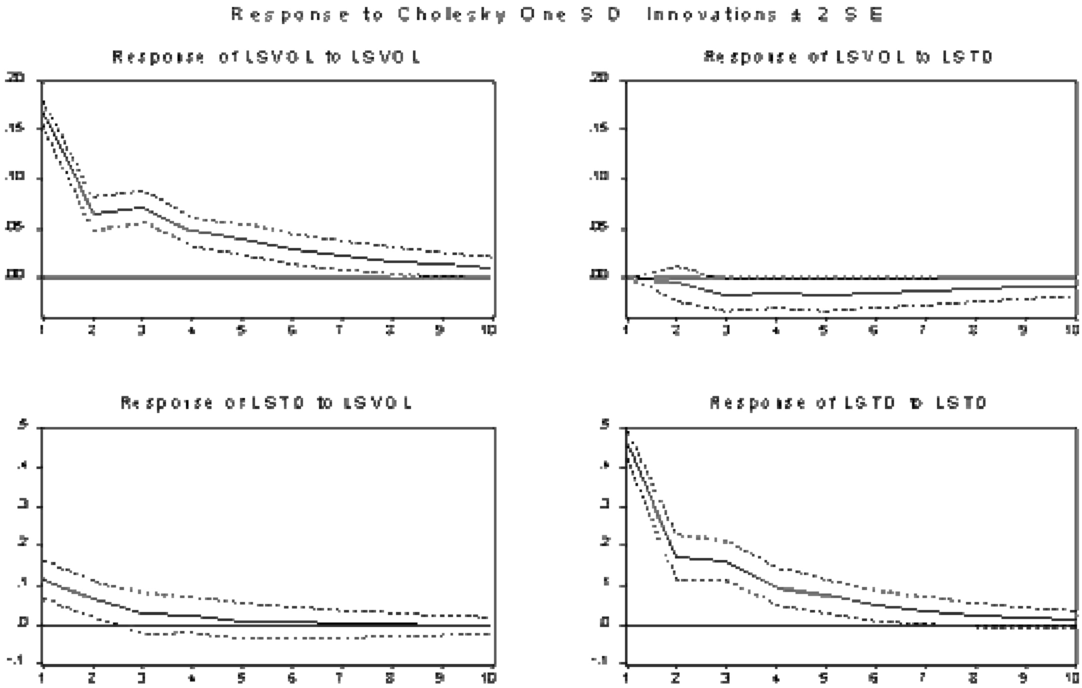


(b) Ordering: (realized volatility (*LSTD*), futures volume (*LFVOL*)

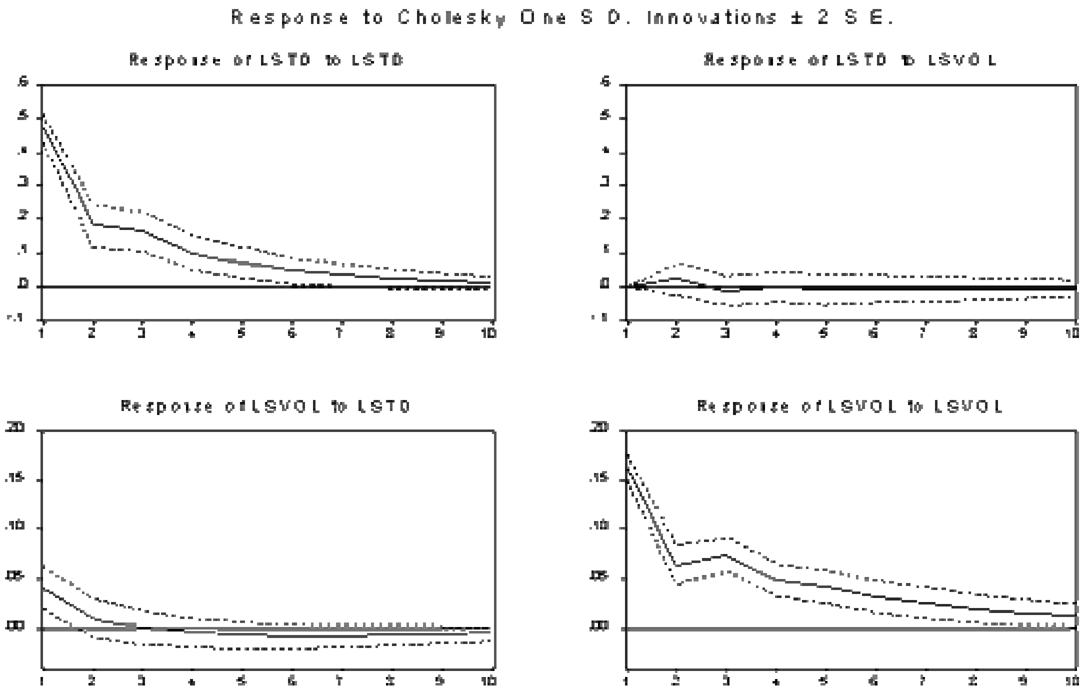


<Figure 4> Impulse Response Function with Realized Volatility (KRW/USD)

(a) Ordering: (spot volume (*LSVOL*), realized volatility (*LSTD*))

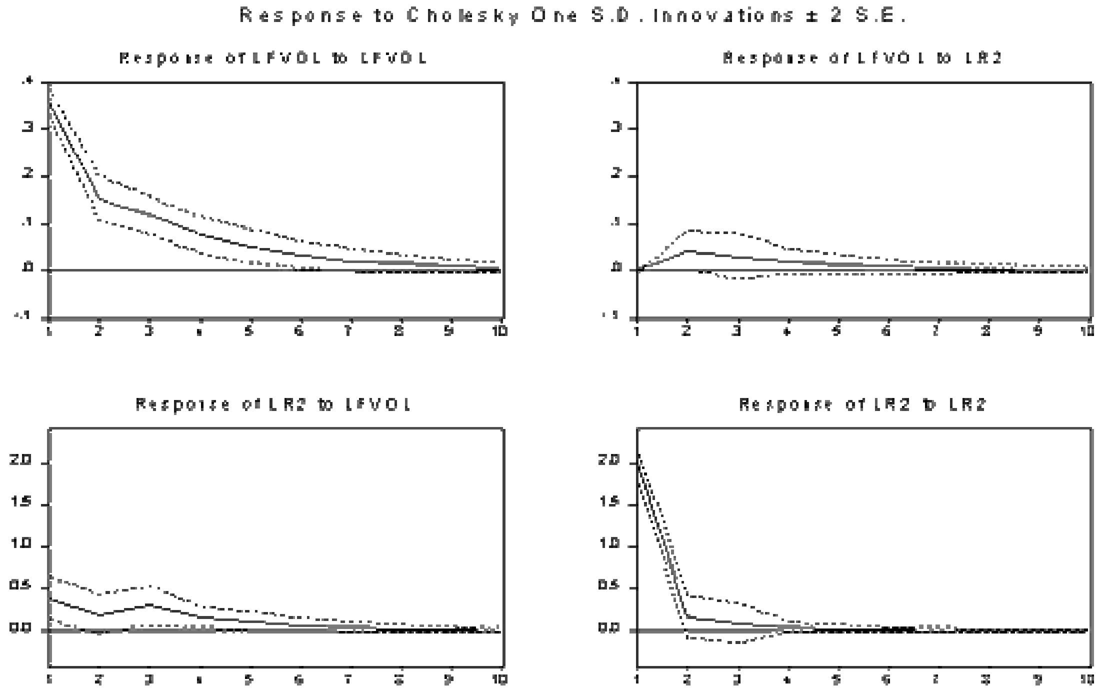


(b) Ordering: (realized volatility (*LSTD*), spot volume (*LSVOL*))

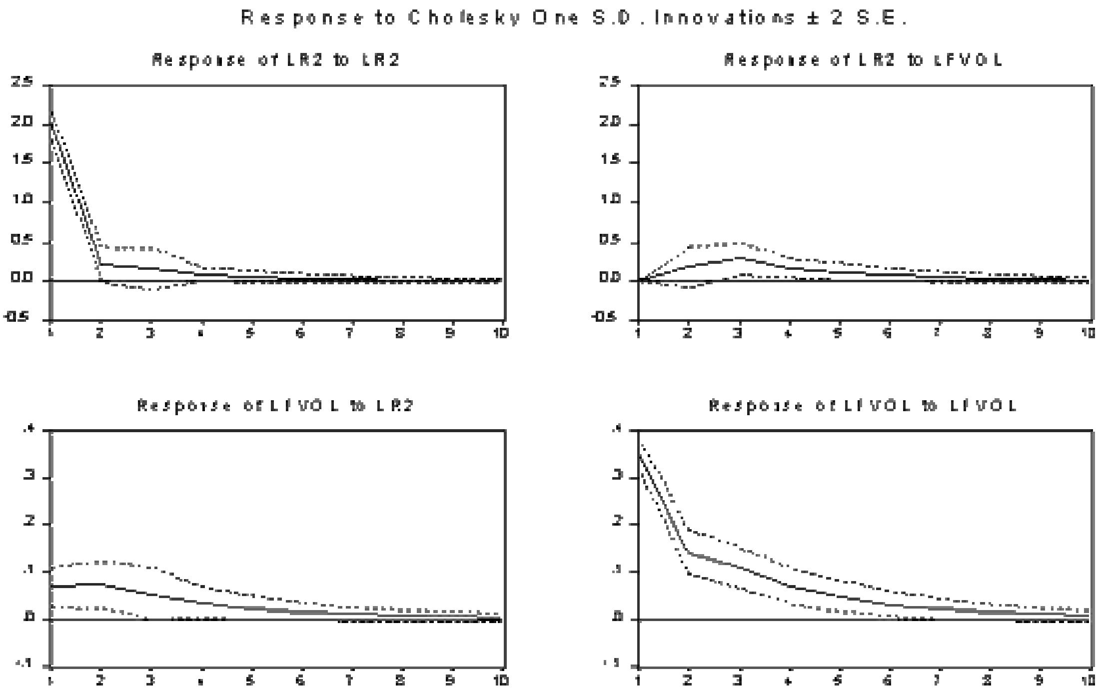


<Figure 5> Impulse Response Function with Square of Returns (KRW/USD)

(a) Ordering: (futures volume (*LFVOL*), square of returns (LR2))

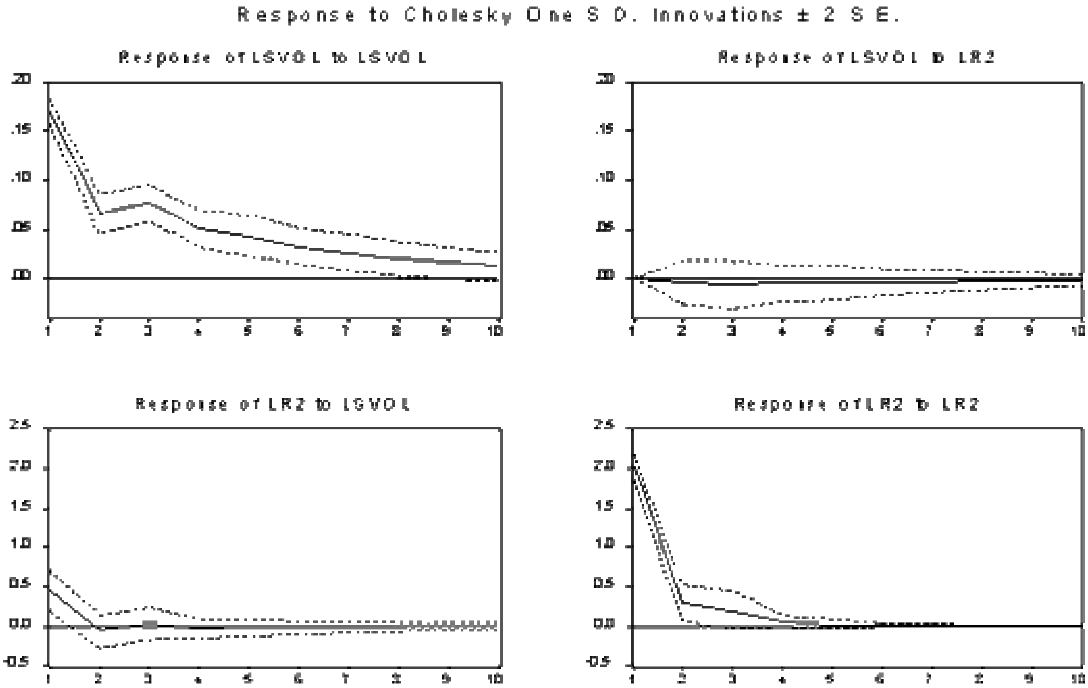


(b) Ordering:(square of returns (LR2), futures volume (*LFVOL*))

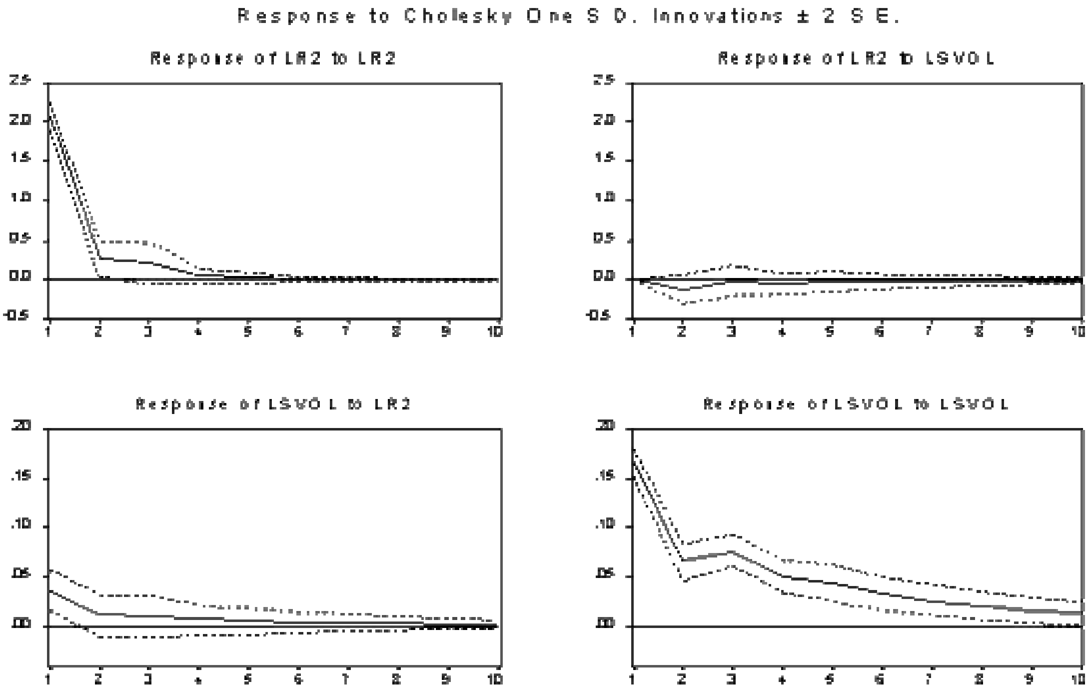


<Figure 6> Impulse Response Function with Square of Returns (KRW/USD)

(a) Ordering: (spot volume (*LSVOL*), square of returns (LR2))

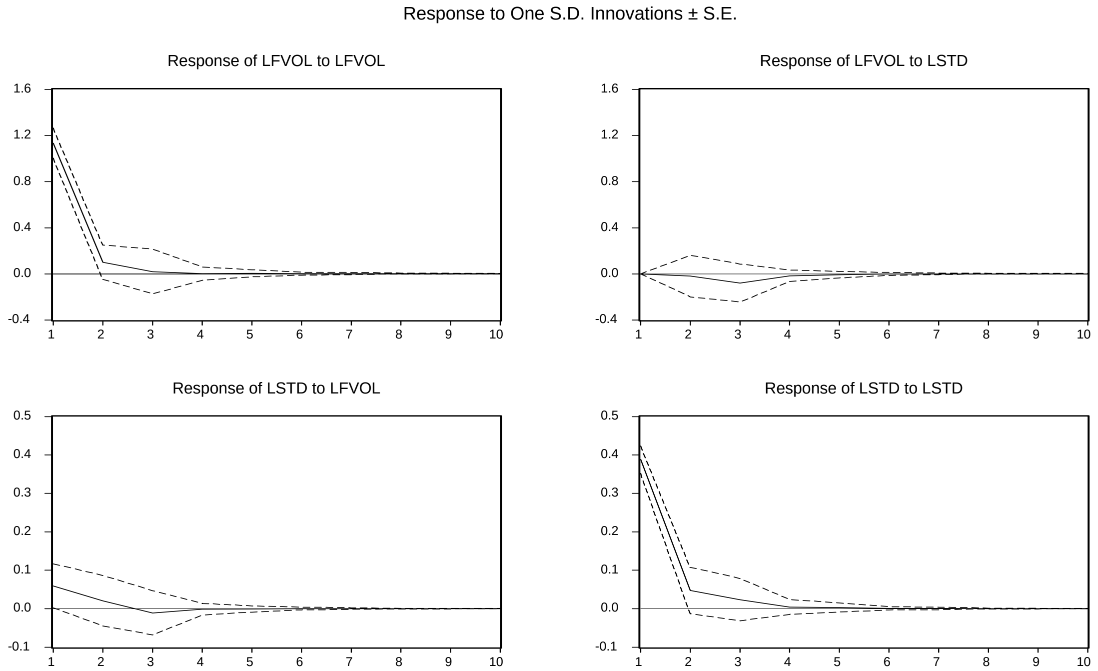


(b) Ordering:(square of returns (LR2), spot volume (*LSVOL*))

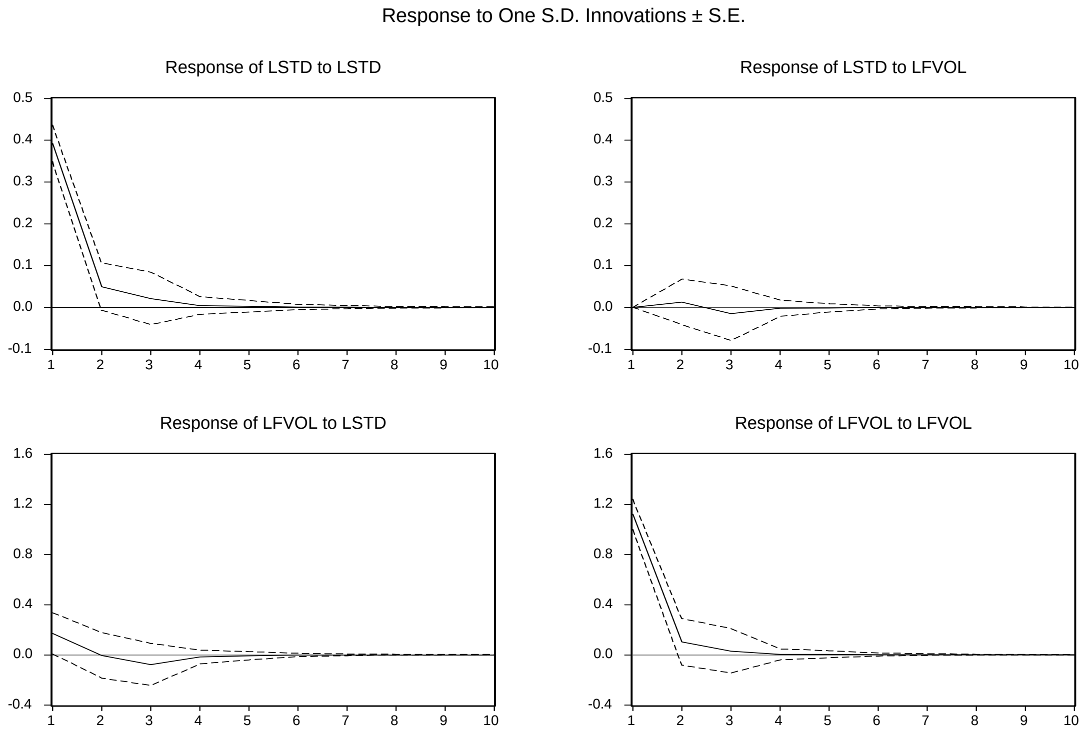


<Figure 7> Impulse Response Function with Realized Volatility (JPY/USD)

(a) Ordering: (futures volume (*LFVOL*), realized volatility (*LSTD*))

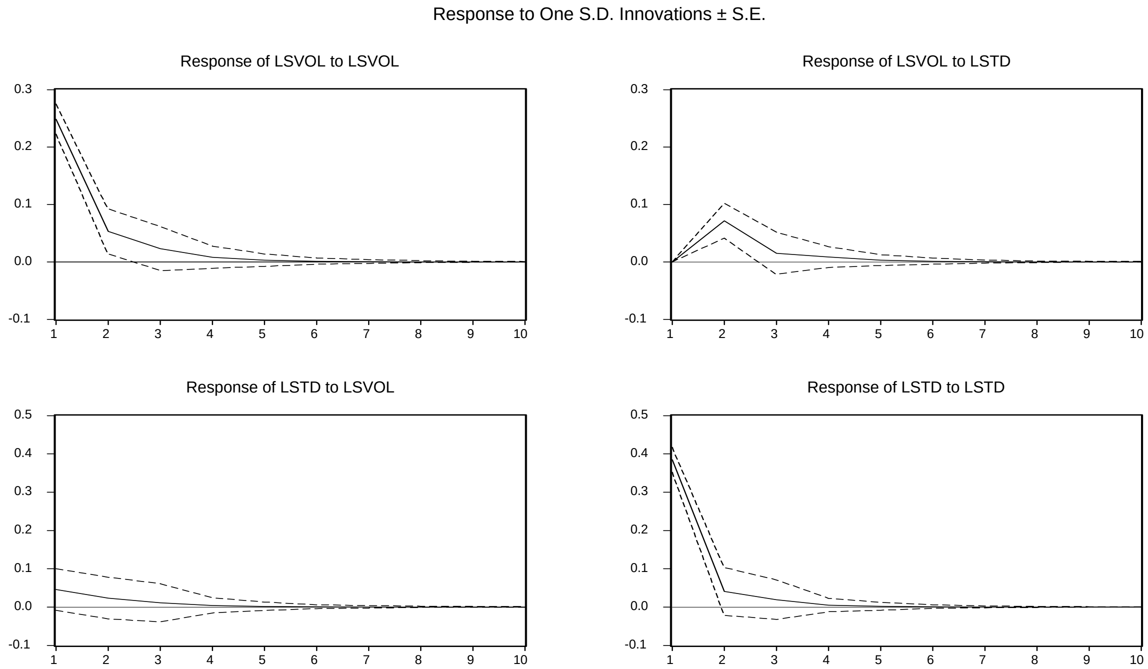


(b) Ordering: (realized volatility (LSTD), futures olume(FVOL))

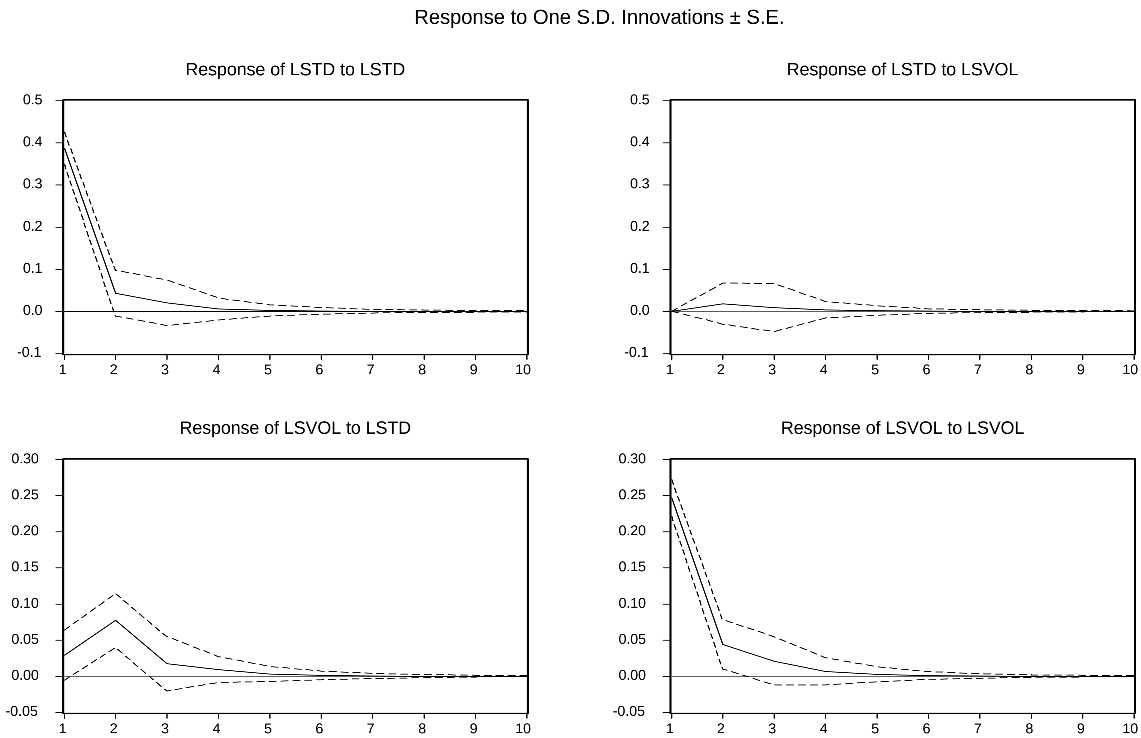


<Figure 8> Impulse Response Function with Realized Volatility (JPY/USD)

*(a) Ordering: (spot volume (*LSVOL*), realized volatility (*LSTD*))*



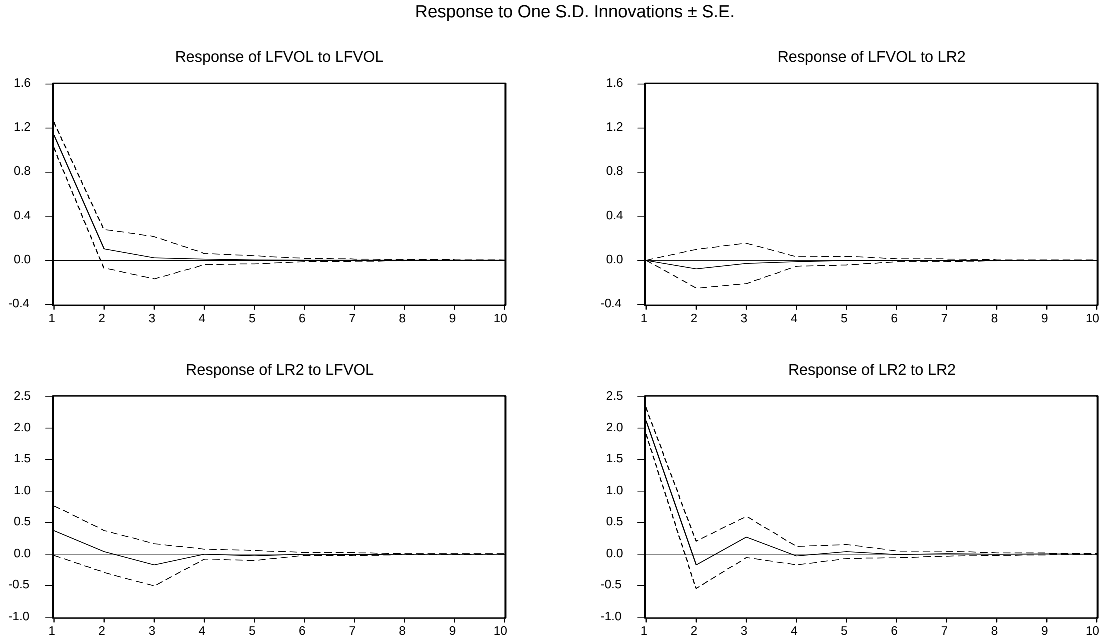
*(b) Ordering: (realized volatility(LSTD),spot volume (*LSVOL*))*



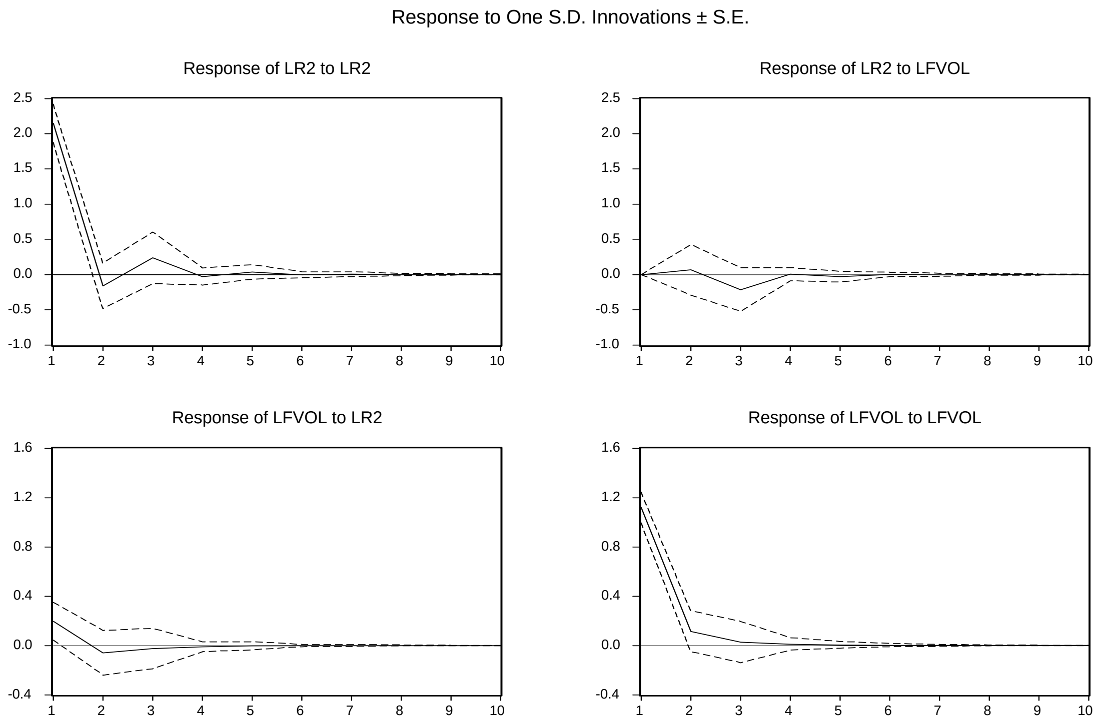
<Figure 9> Impulse Response Function with Square of Returns (JPY/USD)

2) JPY/USD

*(a) Ordering: (futures volume (*LFVOL*), square of returns (LR2))*

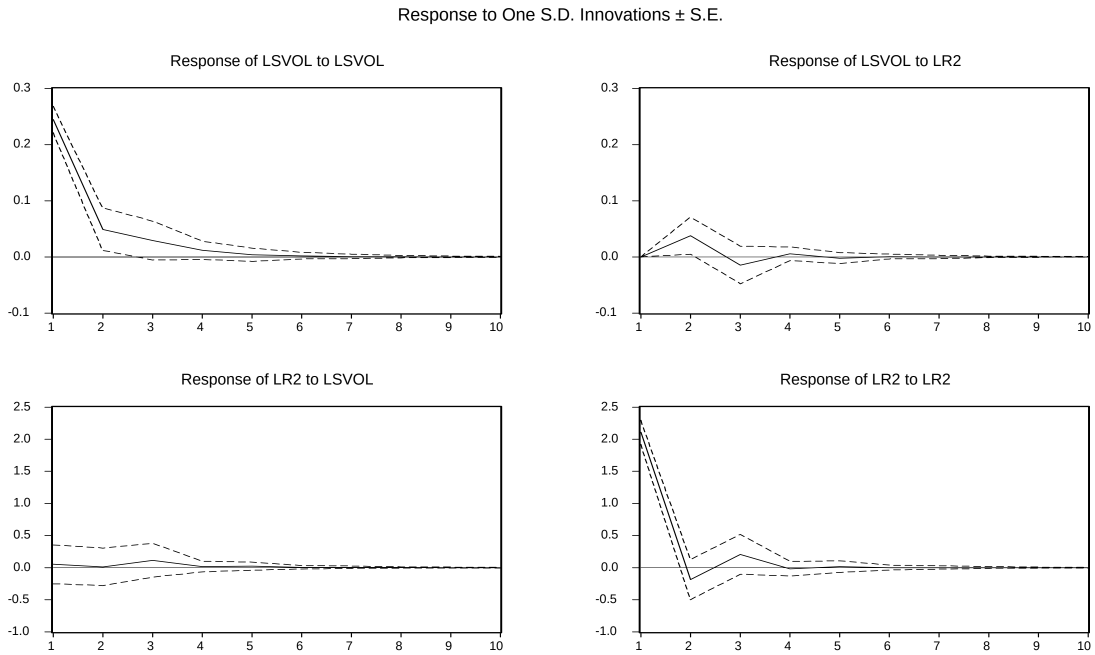


*(b) Ordering:(square of returns (LR2), futures volume (*LFVOL*))*



<Figure 10> Impulse Response Function with Square of Returns (JPY/USD)

(a) Ordering: (spot volume (*LSVOL*), square of returns (LR2))



(b) Ordering:(square of returns (LR2), spot volume (*LSVOL*))