# Volatility and Liquidity:

## Evidence from the JGB Futures Market

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CONTENTS



## 1. INTRODUCTION

The paper presents analyses of the relation between the volatility and liquidity of the Japanese Government Bond (JGB) futures market of the Tokyo Stock Exchange (TSE). For this study, we adopt the volume and the Bid-Ask spread (alternatively, the spread) as a measurement of liquidity.

Various discussions related to the concept and the measurement of liquidity have been made. For instance, Maureen O 'Hara (1995) suggests that minimum transaction costs define high liquidity. In such a situation, the spread is usually narrow and the transaction volume is large. Generally, it can be said that the spread is the transaction cost to an investor. The widening of the spread means that the transaction cost becomes higher. Oppositely, narrowing of the spread means that the transaction cost becomes smaller.

By the argument above, the volume is one measure of liquidity: the larger the volume is, the higher the liquidity of a market. Inferring that narrower spreads mean smaller transaction costs, it can be thought that volume increases as the spread narrows. Therefore, liquidity increases as the spread narrows and volume increases.

Some relation pertains between volatility and liquidity. Volatility is usually a risk index. It can be thought that risk-averse investors want to execute transaction during the transaction time zone when the volatility is smaller (lower). On the other hand, if the investor is the risk neutral, it will be thought that they want to execute transaction at the transaction time zone with a high return — during periods of larger (higher) volatility —

Key words: JGB Futures, Volatility, Volume, Bid-Ask Spread

because the rate of expected return is high. The same will pertain in the case of risk-lover.

For risk-averse investors, as the spread narrows with increased liquidity, the volume increases, and the volatility is smaller. On the other hand, if the investor is risk neutral or risk-lover, as liquidity increases, the spread narrows, the volume is larger, and the volatility is larger.

Consequently, what values do volatility and the spread actually take as the volume increases or decreases? That is, what value does volatility have as a factor to explain the change of liquidity? One purpose of this paper is to clarify the answers to those questions.

First, maximum likelihood is used as the method of analysis considering autocorrelation of data and the problem of endogeneity bias. Then, it is necessary to verify relations in the intraday pattern of the volatility and each intraday pattern of the volume and the spread. Next, the conditional variance is formulated using the GARCH model to verify whether the volume or the spread influences the price as new transaction information.

Results of estimation show that an opposite relation exists between the intraday pattern of the volatility and the intraday pattern of the volume. Some models show a different result. The relation between volatility and the spread is shown to change in the same direction. This result is observed for all models. It is expected that the risk increases concomitantly with the increased transaction cost of the investor. Results show a tendency of countervailing change between the intraday patterns of the volume and the spread. It is inferred that the transaction cost decrease, causing a volume increase.

Moreover, results of the GARCH model including asymmetric volatility show that the volume and the spread are important information as factors that change the volatility.

The remainder of this paper is organized as follows. Section 2 describes precedent studies. Section 3 presents the empirical framework used for this study. Section 4 explains the microstructure of the JGB futures market. Section 5 describes the data used for analyses. In Section 6, we discuss the empirical results. Finally, Section 7 concludes this study.

## 2. PRECEDENT STUDIES

Many precedent studies that undertake analyses of market microstructure and the liquidity: Garman (1976), Copeland and Galai (1983), Glosten and Milgrom (1985), Easley and O 'Hara (1987), Amihud and Mendelson (1987, 1991a, b), Admati and Pfleiderer (1988), Subrahmanyam (1991), Stoll and Whaley (1990), and Huang and Stoll (1994) all present results of such analyses. Many reports explain an investor's behavior related to transaction using the Bid-Ask spread. The spread shows the cost of a transaction: the spread widens if the transaction cost is larger, the spread narrows if the transaction cost is smaller. These inferences are explainable through the transaction behavior of the market maker.

However, neither the market maker nor specialists are associated with the JGB futures market of the TSE. Therefore, the model systems used for precedent research cannot be used for this study as they are. An investor can observe past order flow with the transaction devices. Moreover, when the investor decides an own order and the price, they use macroeconomic fundamentals and the type of trading (either sales or purchase) as new transaction information. At this time, whenever the investor will deal with information traders, the investor receives the loss without fail. To compensate for the loss, the investor executes the order with a slightly higher price (when putting out a sell order) or a slightly lower price (when putting out a buy order).

Therefore, the Bid-Ask spread, as seen in TSE, means the difference between the order prices (the difference between the purchase price and the sales price). The asked quotation and the bid quotation are put out in the JGB futures market (in TSE); then the price at which the seller and the purchaser can execute transaction is different. The transaction is done if the seller's limit order and the purchaser's limit order match. After matching, a difference exists without fail between the sales order price and the purchase order price if orders that are not executed remain in the book. It might be clear that this spread has information related to transactions. Moreover, few situations are thought to exist in which the investor can deal easily because the transaction cost increases as the spread widens. In such a situation, the liquidity of the JGB futures market is low. Oppositely, it is judged that the transaction cost is small if the spread is narrow, and then liquidity is high.

It has been impossible to use such data recently in microstructure research for the securities market in Japan. Therefore, few studies use high-frequency data. It is impossible to analyze the influence caused by the trading system, the price formation, and public information accurately in daily data. Therefore, it is thought that it is necessary to analyze it using high-frequency data. Moreover, it is assumed that it is a problem (measurement noise) to estimate noise greatly compared with the high-frequency data, even if they are low-frequency data (for instance daily data)[(1)].

## 3. MODELS

The relation between the volatility and liquidity is clarified using tick data of the volume (DEKIDAKA), the volatility, and the Bid-Ask spread. Moreover, the relation among the volatility, the volume, and the spread are verified using the GARCH model.

First, we analyze what relations between the intraday pattern of the volatility and each intraday pattern of the volume and the spread using the method of maximum likelihood considering the problem of endogeneity bias. In addition, the conditional variance is formulated using the GARCH model, including the asymmetric volatility; it is verified whether the volume or the spread influences the JGB futures price as new information related to transactions. The GARCH model is general as an analysis that uses the volatility. Asymmetric volatility is included in the model because the characteristic of asymmetry is strong as a change factor of the volatility from the precedent research.

The volume and the spread are adopted as a proxy of liquidity in this study, although the spread, the depth (market thickness), the immediacy, and the resiliency are general proxies of liquidity. The spread is a measurement that expresses the transaction costs of an investor's buying and selling. The smaller the spread, the higher the market liquidity is.

As described earlier, as measures of liquidity, although a market must be evaluated by immediacy and resiliency too, these data cannot be used.

### Volatility, Volume, and Spread

The transaction cost is usually measured using the Bid-Ask spread (Bid price - Ask price). However, when that measure is used, the transaction cost of the investor who orders the Bid and the investor who orders the Ask are calculated twice, as a "round-trip transaction". For that reason, this study does not measure the transaction cost using the (Bid price - Ask price) alone but measures the transaction cost as (Bid price - Ask price) × 1/2. The following quoted spread, $S_t/2$, is used.(2)

$$S_t/2=(b_t-a_t)/2 \tag{1}$$

Where, $a_t$ denotes the Ask price and $b_t$ denotes the Bid price. The quoted spread is half of the difference between the Bid price and the Ask price.

Neither the Ask price nor the Bid price is necessarily equal to the contract price. It is highly probable that transactions have been done between the Ask price and the Bid price. Especially, that probability rises when the spread has widened. It is reportedly appropriate to use not the quoted spread but the effective spread as a measurement of the transactions execution cost when transactions are done within the spread.

The Effective Spread $Z_t$ is formulated as follows.

$$Z_t=|P_t-Q_t| \tag{2}$$
$$Q_t=(a_t+b_t)/2$$

Where, $P_t$ denotes the contract value and $Q_t$ represents the mean value of the Ask price and the Bid price. When an investor and other immediate suppliers have transactions with the informed trader considering the effective spread, it is necessary to cover the transaction fee, the inventory cost, and the asymmetric information cost. In that case, because the effective spread is calculated based on the contract value, the effective spread is a measurement including actual transaction information rather than the quoted spread.

The estimated equation is the following.

$$Volatility_t=b_0+b_1 Volume_t+b_2 Spread_t+e_t \tag{3}$$

In that equation, $Volatility_t$ represents the volatility, $Volume_t$ denotes the volume, and $Spread_t$ is the spread.(3) The volume and the spread explain the intraday pattern of the volatility if coefficients $b_1$ and $b_2$ are statistically significant. Maximum likelihood method is used for this study because of the problem of endogeneity bias.

Expected sign of each coefficient

| | $b_0$ | $b_1$ | $b_2$ |
|---|---|---|---|
| Eq. (3) | ± | − | + |

The negative coefficient of $b_1$ signifies a volatility decrease as the volume increases. The positive coefficient of $b_2$ represents that the volatility increases as the spread widens.

### The GARCH model including asymmetric volatility

Next, the GARCH (1, 1) model is used to formulate the volatility.(4) First, the AR (1) process to the model returns the following.

$$R_t = a_0 + a_1 R_{t-1} + e_t \tag{4}$$

In that equation, $R_t$ denotes the return in period ($t$); $e_t$ denotes unexpected returns. Next, the conditional variance is defined as

$$h_t = \eta + \xi e_{t-1}^2 + \lambda h_{t-1}, \tag{5}$$

where $h_t$ denotes the conditional variance of $e_t$. Coefficient $\xi$ indicates the extent to which a volatility shock this period ($t$) feeds through to the next period's volatility ($t+1$). Furthermore, $\xi + \lambda$ measures the rate at which this effect subsides over time.

In addition, to verify the asymmetric volatility, eq. (6) is used for this study. According to Black (1976), volatility mainly responds asymmetrically after a large shock: either very good or very bad news. For that reason, this paper uses the extended specification to capture such a phenomenon. Generally, the price falls after unanticipated bad news, and the price rises after unanticipated good news. In the next specification, the conditional volatility is shown by $h_t$ as follows.

$$h_t = \eta + \lambda h_{t-1} + \xi e_{t-1}^2 + \gamma D_{t-1}^{-} e_{t-1}^2 \tag{6}$$

Where, $D_{t-1}^{-} = 1$ if $e_{t-1}$ is negative at period ($t-1$) and $D_{t-1}^{-} = 0$, otherwise, E ($e_t$)$=0$, Var ($e_t$)$=h_t$.

As a result of the estimate, if, $\gamma > 0$, then the asymmetric volatility will be verified. Furthermore, if so, volatility rises in the subsequent interval when the price drops unexpectedly, rather than when the price rises unexpectedly.

Market participants react more strongly to unfavorable information (the error term residual is negative, bond prices fall) than favorable information (the error term residual is positive, bond prices rise) if the asymmetric volatility is observed in the JGB futures market. It is inferred that this phenomenon means that the market participants have a sentiment related to the investment.

In addition, the information effect of the volume is apparent in the next equation. *Volume* ($t$), which shows the volume, is added to eq. (6).

$$h_t = \eta + \lambda h_{t-1} + \xi e^2_{t-t} + \gamma D^-_{t-1} e^2_{t-t} + \theta Volume_t \quad (7)$$

Therein, the intraday pattern of the volume (DEKIDAKA) will explain the intraday pattern of the volatility if a coefficient $\theta$ is statistically significant. Here, the sign of the coefficient demands particular attention.

The volatility will increase as the volume increases if the coefficient is significant with a positive sign. The volatility will decrease as the volume increases if the coefficient is significant with a negative sign.

In the next equation, the information effect of the spread is analyzed: *Spread* ($t$) denotes the proxy of the spread.

$$h_t = \eta + \lambda h_{t-1} + \xi e^2_{t-t} + \gamma D^-_{t-1} e^2_{t-t} + \phi Spread_t \quad (8)$$

Here, if coefficient $\phi$ is significant, then the intraday pattern of the spread explains the intraday pattern of the volatility. The expected sign of the coefficient is positive. The volatility is expected to increase too, as the spread widens.

Finally, whether the intraday pattern of the volatility is explained by both variables of the volume, the spread is verified in the next equation.

$$h_t = \eta + \lambda h_{t-1} + \xi e^2_{t-t} + \gamma D^-_{t-1} e^2_{t-t} + \theta Volume_t + \phi Spread_t \quad (9)$$

The expected signs of the coefficient of $\theta$ and $\phi$ are a minus and a plus respectively.[(5)]

## 4. THE JGB FUTURES MARKET MICROSTRUCTURE

In the TSE, the transaction session times are 9:00AM－6:00PM, divided into three sessions. The first session (ZENBA) is 9:00AM－11:00AM. The second session (GOBA) is 12:30PM－3:00PM. The evening session is 3:30PM－6:00PM.

Two matching algorithms are adopted in the JGB futures market of the TSE. The first, the Itayose algorithm, is used mainly to determine the opening and closing prices of each trading session. The method is used when the market opens (YORITSUKI) and when the market closes (HIKE).

In ITAYOSE, all quotes (orders) before the contract price are recorded in the order book (ITA). They are considered to be simultaneous orders. Furthermore, it is matched from the highest price order with a high priority level (price priority principle). Moreover, the prices that match quantitatively are decided. The decided price is assumed to be a single contract price; the bargain (transaction) is concluded with the decided price.

The second, the Zaraba algorithm, is used during trading sessions to match orders continuously under price priority and time precedence principles. This is a method used in the transaction time other than opening and closing. After the opening price is decided, this Zaraba method is used until the closing price is decided. The bargain is individually concluded on a first-come-first-served basis during the transaction session; many contract prices are decided continuously.

All JGB futures transactions are executed in accordance with the auction market principle: price priority and time precedence.

## 5. DATA

This section presents a description of the data used for analyses: JGB futures. This study uses high-frequency data of the JGB futures to examine the characteristics of the intraday pattern of volatility. The sample period is April 1, 2003 – March 31, 2004. The sample period has 245 transaction business days. Furthermore, there are 426 samples in one business day; in all, the samples are 104370.[(6)]

The data are obtained from "KIKKEI NEEDS (Tick Saiken Sakimono Option)". The return of JGB futures is calculated for every interval. First, the contract price data are made. The contract price of the interval immediately before that is used when transactions are not contracted at a certain interval and the contract price has not been described in the book (ITA). This means that new information has not been brought to the market. The quotes are also similar. In addition, as for the quotes, we have selected the combination of the Bid price and the Ask price immediately before the transaction is made.

According to Huang and Stoll (1996), spreads of three kinds are used for this study. These are the spread, the quote spread, and the effective spread.

Statistics of the contract price, the volume, and the Bid-Ask spread are described in Table 1. Figures 1–3 depict histograms of the three spreads. In these figures, $S$ signifies the spread width. The unit of $S$ is 1/100 yen. Moreover, the correlation between the volatility and the volume is weak, although the respective correlations of time series data are shown in Table 2. Furthermore, the correlation of volatility and the three spreads is weak. Next, the correlation of the volume and the spread is also weak. A problem of multicollinearity would probably not arise even if they were used simultaneously for estimation.

Table 1 Statistics of variables

| | Price | Return | Volatility | Volume | Spread | Quoted Spread | Effective Spread |
|---|---|---|---|---|---|---|---|
| Mean | 13994.972 | −0.000038 | 0.0070712 | 14.442608 | 1.29607167 | 0.648035834 | 0.631211076 |
| Standard deviation | 265.72857 | 0.0153607 | 0.01363636 | 126.58615 | 1.5650212 | 0.7825106 | 0.71528027 |
| Variance | 70611.673 | 0.00023595 | 0.00018595 | 16024.054 | 2.44929135 | 0.612322839 | 0.511625865 |
| Kurtosis | −1.039902 | 311.625424 | 476.954274 | 860.91898 | 1401.26026 | 1401.260257 | 1505.778667 |
| Skewness | 0.4178135 | −3.1118635 | 12.04522 | 24.602158 | 31.3864273 | 31.3864273 | 30.45679327 |
| Observations | 104370 | 104370 | 104370 | 104370 | 104370 | 104370 | 104370 |

Table 2　Correlation

| | Price | Return | Volatility | Volume | Spread | Quoted Spread | Effective Spread |
|---|---|---|---|---|---|---|---|
| Price | 1 | | | | | | |
| Return | 0.0037 | 1 | | | | | |
| Volatility | −0.1896 | −0.0658 | 1 | | | | |
| Volume | 0.0022 | −0.0164 | 0.2733 | 1 | | | |
| Spread | −0.0996 | 0.0292 | 0.1939 | 0.1768 | 1 | | |
| Quoted Spread | −0.0996 | 0.0292 | 0.1939 | 0.1768 | 1 | 1 | |
| Effective Spread | −0.1077 | −0.0409 | 0.2935 | 0.2102 | 0.6428 | 0.6428 | 1 |

Fig. 1　Spread

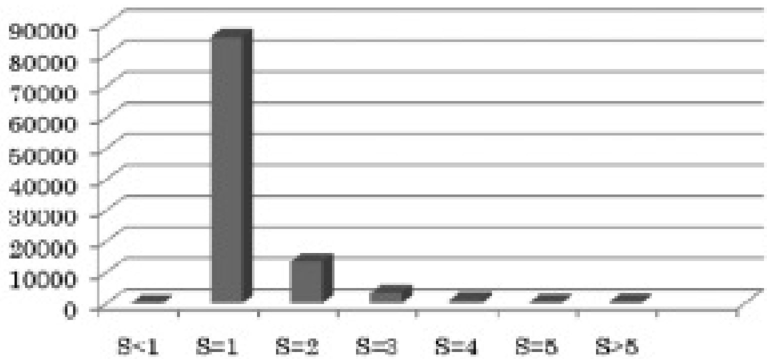



Fig. 2　Quoted Spread

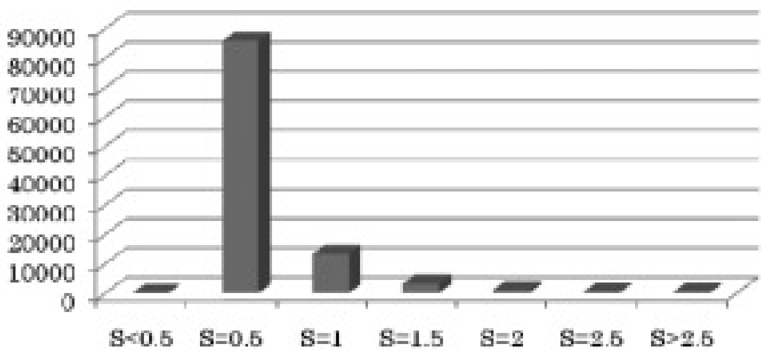
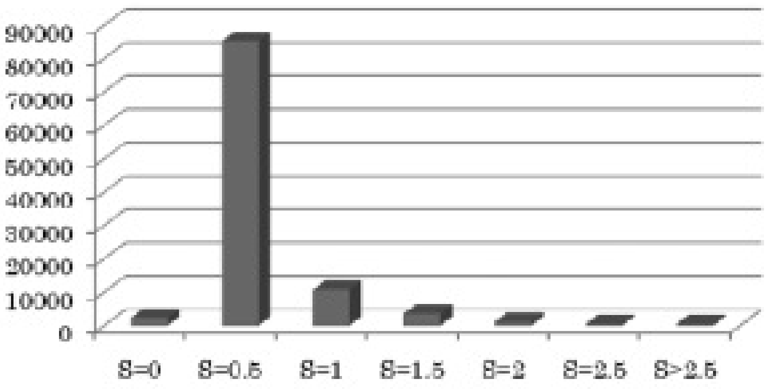



Fig. 3　Effective Spread



## 6. EMPIRICAL RESULTS

From the results of estimation expressed in Table 3, when the volatility is a dependent variable and the volume and the spread are independent variables (models 5-7), the intraday pattern of the volume and the spread explains the intraday pattern of the volatility. Moreover, the coefficients of three spreads are significant and positive, as expected. However, the coefficient of the volume is unexpectedly positive in the results of models (models 5-7).

The coefficient of that is significant and positive when the volume is an explanatory variable (model 1). The coefficients of those are significant and positive when the spread is an independent variable (models 2-4).

Those results correspond to the results of models 5-7. However, the coefficient of the volume is positive. This result is not expected. Moreover, the intraday pattern of the volatility and the intraday pattern of the volume change are in the same direction. The intraday pattern of three spreads and that of the volatility change in the same direction. This relation shows that the spread widens; then the volatility increases.

Moreover, although it is not described in detail here, when the independent variables are the volatility and the spread, and the dependent variable is the volume, the intraday pattern of the volatility and the intraday pattern of the spread explain the intraday pattern of the volume. The coefficient of three spreads is significant with an expected minus sign. The coefficient of the volatility is a plus sign in each model. The coefficient is positive and significant when the volatility is an independent variable. The coefficient of the spread is significant and negative when the spread is an independent variable.

These results correspond to results of the model described above. The coefficient of the volatility is positive. The intraday pattern of the volatility and the intraday pattern of the volume change in the same direction. On the other hand, the intraday pattern of three spreads and the intraday pattern of the volume change in an opposite direction. Results show that the volume decreases as the spread widens. Consequently, transaction costs rise and the volatility (transaction risk) rises: the investor will therefore be deterred from performing transactions.

Next, Table 4 shows the result of the GARCH model considering the asymmetric volatility, which is the benchmark model. The asymmetric volatility is confirmed significantly. Moreover, the effect of GARCH is significant; also, the effect continues for a long term.

Furthermore, as Table 5 shows, when the volume is added to the benchmark model, the coefficient of the volume is significant and negative. The intraday pattern of the volume explains the intraday pattern of the volatility from this result. Results show that the risk decreases as the volume increases. This is an expected result, but it does not correspond to the result derived above (eq. 3).

As Table 6 shows, when the spread is added to the benchmark model (here, only the effective spread is used), the coefficient of the spread is significant and positive. This is an expected result: the risk decreases as the spread widens.

Finally, as Table 7 portrays, when the volume and the spread are added to the benchmark model, the coefficient of the volume is significant and negative, showing that an increase in the volume and a reduction of the volatility are generated simultaneously. Moreover, the coefficient of the effective spread is significant and positive. Consequently, an extension in the spread and an increase of the volatility are generated simultaneously. Both results correspond to the expected results.

Results described above show that, with regard to the persistence of volatility, the persistence is lessened compared with the result of the benchmark model. The volume and the spread are important as persistence factors of the volatility. Results show that the volume and the spread significantly influence the transaction of JGB futures. Judging the strength of those influences from each coefficient, the spread influence is stronger.

Regarding asymmetric volatility, it is confirmed in all models. Therefore, irrationality (illogical behavior) exists in an investor's transaction behavior.

Table 3 Dependent variable Volatility

| | Model1 | Model2 | Model3 | Model4 | Model5 | Model6 | Model7 |
|---|---|---|---|---|---|---|---|
| Constant | 0.006635*** | 0.000617 | 0.000617 | −0.001004* | 0.001500** | 0.004999*** | −0.000029 |
| | 0.000053 | 0.000634 | 0.000612 | 0.000534 | 0.000584 | 0.000336 | 0.000797 |
| Volume | 0.000030*** | | | | 0.000025*** | 0.000027*** | 0.000021*** |
| | 0.000003 | | | | 0.000003 | 0.000003 | 0.000003 |
| Spread | | 0.004125*** | | | 0.003074*** | | |
| | | 0.000762 | | | 0.000522 | | |
| Quoted Spread | | | 0.008251*** | | | 0.002604*** | |
| | | | 0.001427 | | | 0.000454 | |
| Effective Spread | | | | 0.011200*** | | | 0.008818*** |
| | | | | 0.000865 | | | 0.001570 |

'***', '**' and '*' respectively indicate that the corresponding coefficients are statistically significant at the 1%, 5% and 10% levels. There is standard error in the lower of the coefficient.

Table 4 Benchmark Model eq. (6)

| | Variable | Coeff | Std Error |
|---|---|---|---|
| 1 | Constant | 2.52E-10 | 2.57E-11*** |
| 2 | $\lambda$ | 0.0868 | 0.0006*** |
| 3 | $\xi$ | 0.0679 | 0.0012*** |
| 4 | $\gamma$ | 0.8429 | 0.0048*** |

'***', '**' and '*' respectively indicate that the corresponding coefficients are statistically significant at the 1%, 5% and 10% levels.

Table 5 Benchmark Model with Volume eq. (7)

| | Variable | Coeff | Std Error |
|---|---|---|---|
| 1 | Constant | 8.14E-07 | 1.51E-07*** |
| 2 | $\lambda$ | 0.5859 | 0.0074*** |
| 3 | $\xi$ | 0.0038 | 0.0004*** |
| 4 | $\gamma$ | 0.0406 | 0.0002*** |
| 5 | $\theta$ | −3.29E-10 | 8.02E-11*** |

'***', '**' and '*' respectively indicate that the corresponding coefficients are statistically significant at the 1%, 5% and 10% levels.

Table 6 Benchmark Model with Effective Spread eq. (8)

| | Variable | Coeff | Std Error |
|---|---|---|---|
| 1 | Constant | 1.88E-10 | 2.40E-10 |
| 2 | $\lambda$ | 0.2628 | 0.0015*** |
| 3 | $\xi$ | 0.0866 | 0.0017*** |
| 4 | $\gamma$ | 0.9756 | 0.0068*** |
| 5 | $\phi$ | 1.16E-07 | 2.36E-09*** |

'***', '**' and '*' respectively indicate that the corresponding coefficients are statistically significant at the 1%, 5% and 10% levels.

Table 7 Benchmark Model with Volume and Effective Spread eq. (9)

| | Variable | Coeff | Std Error |
|---|---|---|---|
| 1 | Constant | 3.47E-08 | 5.96E-09*** |
| 2 | $\lambda$ | 0.0199 | 0.0005*** |
| 3 | $\xi$ | 0.0227 | 0.0005*** |
| 4 | $\gamma$ | 0.6578 | 0.0057*** |
| 5 | $\theta$ | −2.17E-11 | 6.81E-12*** |
| 6 | $\phi$ | 3.97E-07 | 7.19E-09*** |

'***', '**' and '*' respectively indicate that the corresponding coefficients are statistically significant at the 1%, 5% and 10% levels.

## 7. CONCLUSION

This paper presented analyses of the relation between the volatility and liquidity of the JGB futures market of the TSE.

The maximum likelihood method is used for analyses considering autocorrelation of data and the problem of endogeneity bias. First, it is necessary to verify what relations in the intraday pattern of the volatility and each intraday pattern of the volume and the spread. Next, the conditional variance is formulated using the GARCH model. Results verify whether the volume or the spread influences the price as new transaction information.

Estimations show that a relation that changes in the opposite direction pertains between the intraday pattern of the volatility and the intraday pattern of the volume. The risk decreases as the volume increases. However, in some models, a different result is obtained.

Regarding the relation between the volatility and the spread, it is shown to change in the same direction. This result is observed from all models. It is expected that the risk increases concomitantly with the transaction cost of the investor. Results show that a characteristic of change in the opposite direction exists between the intraday patterns of the volume and that of the spread. Transaction costs are inferred to become smaller and that the volume increases.

Moreover, the result of the GARCH model, including that of asymmetric volatility, shows that the volume and spread are important information as factors that change the volatility. Regarding the strength of those influences, the spread influence is inferred to be stronger.

## REFERENCES


Admati, A., and P. Pfleiderer (1988) "A Theory of Intraday Trading Patterns," *Review of Financial Studies* 1, 3-40.

Amihud, Y., and H. Mendelson [1987] "Trading Mechanisms and Stock Returns: An Empirical Investigation," *Journal of Finance* 42, 533-553.

Amihud, Y., and H. Mendelson [1991a] "Market Microstructure and Price Discovery on the Tokyo Stock Exchange," in *Japanese Financial Market Research* edited by W. T. Ziemba. 169-196.

Amihud, Y., and H. Mendelson [1991b] "Volatility, Efficiency, and Trading: Evidence from the Japanese Stock Market," *Journal of Finance* 46, 1765-1789.

Amihud, Y., and H. Mendelson [2005] Liquidity and Asset Pricest, Foundation and Trends in Finance, Volume 1 Issue 4.

Black, F. [1976] "Studies of Stock Market Volatility Changes,"1976 Proceedings of the American Statistical Association, Business and Economics Statistic Section, 177-181.

Bollerslev, T. [1986] "Generalized autoregressive conditional heteroskedasticity," *Journal of Econometrics*, 31, 307-327.

Campbell, J., Lo, A., & MacKinlay, A. [1997] The Econometrics of Financial Markets, Princeton University Press.

Copeland, T., and D. Galai [1983] "Information Effects on the Bid-Ask Spread," *Journal of Finance* 38, 1457-1469.

Easley, D., and O'Hara, M. [1987] "Price, Trading Size, and Information in Securities Markets," *Jorunal of Financial Economics* 19, 69-90.

Graman, M. B. [1976] "Market microstructure," *Journal of Financial Economics* 3, 257-275.

Glosten, L., and P. Milgrom [1985] "Bid, Ask and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders," *Journal of Financial Economics* 14, 465-474.

Huang, R., and Stoll, H [1994] "Market Microstructure and Stock Return Predictions," *The Review of Financial Studies* 7, 179-213.

Huang, R., and Stoll, H [1996] "Dealer versus auction markets: A paired comparison of execution costs on NASDAQ and the NYSE," *Journal of Financial Economics* 41, 313-357.

O'Hara, M. [1995] *Market Microstructure Theory*, Blackwell Publishers.

Subrahmanyam, A. [1991] "Risk Aversion, Market Liquidity, and Price Efficiency," *Review of Financial Studies* 4, 417-442.

Stoll, H. R. and R. E. Whaley [1990] "Stock Market Structure and Volatility," *Review of Financial Studies* 3, 37-71.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(1) See Amifud, Mendelson and Pedersen (2005).

(2) This index was used to show which investor causes the transaction cost: the bid side or the ask side.

(3) Three kinds of spread are individually presumed without using them at the same time.

(4) As Bolleslev (1986), and Campbell, Lo and MacKinlay (1997) demonstrate, the GARCH (1, 1) model fulfills the principle of the saving and can capture the effect of ARCH of higher order. Moreover, when R (return) was checked using the Box-Jenkins method, the auto-correlation is admitted in the squared residuals from the ACF coefficient, the PACF coefficient, and the $Q$ statistic in this paper. There is no unit root by the unit root tests of the ADF and the PP.

(5) Not a normal distribution but a $t$ distribution is used though the method of maximum likelihood when estimating.

(6) However, the market is open only in the morning (Zenba) on December 30, 2003 and January 5, 2004. Therefore, these two transaction days were excluded from the sample. Moreover, one interval is one minute. For instance, in the first session (Zaraba), it is divided as follows, 9:00–9:01, 9:01–9:02, …, 10:59–11:00.

[Abstract]

# Volatility and Liquidity:
## Evidence from the JGB Futures Market

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This paper presents analysis of the relation between the volatility and liquidity of the Japanese Government Bond (JGB) Futures Market of the Tokyo Stock Exchange (TSE). Results show an inverse relation between the intraday pattern of volatility and that of the trade volume. Risk decreases as the volume increases. Volatility and the spread change in the same direction. Risk increases concomitantly with the transaction cost of the investor. Moreover, results show that the volume and the spread are important information as change factors of the volatility of JGB futures.

Key words: JGB Futures, Volatility, Volume, Bid-Ask Spread