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Empirical Relation among Return, Volatility and Liquidity of the JGB Futures： the EGARCH-M Model

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CONTENTS

1. Introduction

This paper presents examination of the empirical relation among return, volatility and liquidity of the Japanese Government Bond (JGB) Futures market of the Tokyo Stock Exchange (TSE). We use the datasets of volume, bid price, and ask price as a measurement of liquidity to assess that relation.

Various analyses have been made of the market microstructure and the measurement of liquidity. For instance, 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) describe results of such analyses. Many reports explain an investor's behavior related to transactions using a bid-ask spread. The bid-ask spread represents the cost of a transaction: the bid-ask spread widens if the transaction costs are larger; it narrows if the transaction costs are smaller. These inferences are explainable through the transaction behavior of the market-maker.

Maureen O'Hara (1995) suggests that minimum transaction costs define high liquidity. In such a situation, the bid-ask spread is usually narrow and the transaction volume is large. Generally, the bid-ask spread probably represents the transaction cost to an investor. A widening bid-ask spread signifies increasing transaction costs. Oppositely, narrowing implies decreasing transaction costs.

Based on that premise, volume is one measure of liquidity: the larger the volume is, the higher the market liquidity. Inferring that narrower spreads signify smaller transaction costs, it can be inferred that volume increases as the spread narrows. Therefore, liquidity increases as the spread narrows and volume increases.

Some relation pertains to volatility and liquidity. The volatility is usually regarded as a risk index. Risk-averse investors might want to execute transactions during a time when the volatility is lower. On the other hand, a risk-neutral investor might want to execute transactions at a time with a high return—during periods of higher volatility—because the expected rate of return is high. The same will ap-

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

ply in the case of a risk-seeking (lover) investor.

For risk-averse investors, as the spread narrows with increased liquidity, the volume increases, and the volatility is lower. On the other hand, if the investor is risk neutral or risk-seeking, then the spread narrows as liquidity increases; the volume is larger, and the volatility is higher.

However, neither market-makers nor specialists are associated with the JGB futures market of the TSE. Therefore, the model systems used for precedent research are not useful for this study. An investor can observe past order flow with transaction devices. Moreover, when the investor decides an order and a price, they use macroeconomic fundamentals and the type of trading (either sales or purchase) as new transaction information. At such a time, whenever the investor deals 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 placing a sell order) or a slightly lower price (when placing a buy order).

Therefore, the bid-ask spread, as seen for the TSE, represents the difference between the order prices (the difference between the purchase price and the sales price). The asked quotation and the bid quotation are made public in the JGB futures market (in TSE). Then the price at which the seller and the purchaser can execute a transaction is different. The transaction is completed 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 to an observer 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 JGB futures market liquidity is low. Oppositely, it is judged that the transaction cost is small if the bid-ask spread is narrow; 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, accurately, those influences on daily data that are respectively attributable to the trading system, price formation, and public information. Therefore, it is necessary to analyze those factors using high-frequency data. Moreover, it is assumed that estimation using high-frequency data is greatly hindered by measurement noise, which would be true even using low-frequency data (e.g. daily data)[1].

This paper describes volatility measurements and reveals the relation among return, volume, and bid-ask spread. We estimate the EGARCH-M model. First, we estimate a conditional volatility. A conditional mean is estimated using the EGARCH effect, the volume and the bid-ask spread. Then, it is necessary to verify relations in the intraday pattern of return and each intraday pattern of volatility, volume, and the bid-ask spread.

Results of estimation show that an opposite relation exists between the intraday pattern of the return and the intraday pattern of the volume in some models. The relation between return and the effective spread is shown to change in the opposite direction. It is expected that the risk decreases concomitantly with the increased transaction cost of the investor. Results show a tendency of countervailing change between the intraday patterns of volume and the effective spread. It is therefore inferred that the transaction costs decrease, engendering increased volume.

Moreover, results of EGARCH model show that volatility clustering and volatility asymmetry are verified significantly.

The remainder of this paper is organized as follows. Section 2 presents a description of the empirical framework used for this study. Section 3 explains the data used for analyses. In Section 4, we discuss the empirical results. Finally, Section 5 concludes this study.

2. Models

The relation among return, volatility, and liquidity are clarified using tick-by-tick data of the return, volume, bid price, and ask price.

First, we analyze the prevailing relations between the intraday pattern of return and each intraday pattern of the volatility, the volume, and the bid-ask spread using EGARCH (1, 1)-M model; it is verified whether volatility, volume or bid-ask spread influences the JGB futures return as new information related to transactions. The EGARCH 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. According to Black (1976), volatility mainly responds asymmetrically after a large shock: either very good or very bad news. Consequently, this paper uses extended specifications to capture such a phenomenon. Generally, the price falls after unanticipated bad news, and the price rises after unanticipated good news. Furthermore, if so, volatility rises in the subsequent interval when the price drops unexpectedly, rather than when the price rises unexpectedly.

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

The EGARCH (1,1) -M model

The purpose of this paper is to measure the volatility and to reveal the relation of the return, the volume and the bid-ask spread. To this end, the EGARCH (1, 1) -M specification is used to formulate the conditional volatility[2]. First, I adopt the following equations for the conditional mean (1).

$$R_t = a_0 + a_1 h_t + e_t \qquad (1)$$

In equation (1), R_t denotes the conditional mean during period (t); e_t the return innovation at (t), which are assumed to be normally distributed. The conditional volatility is defined as (2). In a word, h_t denotes the conditional variance of e_t.

Next, Nelson's (1991) exponential GARCH (1,1) is adopted for estimation of the conditional volatility by the following specification.

$$\log h_t = c + a\left|e_{t-1}\right| / \sqrt{h_{t-1}} + b \log h_{t-1} + d e_{t-1} / \sqrt{h_{t-1}} \qquad (2)$$

Therein, $d < 0$, h_t tends to rise (fall) as a consequence bad (good) news. Market participants react more strongly to unfavorable information than to favorable information if 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. Moreover, coefficient b measures the volatility persistence.

Volume

In addition, the information effect of the volume is apparent in the following mean equation. *Volume* (t), which shows the volume, is added to eq. (1).

$$R_t = a_0 + a_1 h_t + \theta Volume_t + e_t \qquad (3)$$

Therein, the intraday pattern of the volume will explain the intraday pattern of the return if a coefficient θ is statistically significant. Here, the sign of the coefficient demands particular attention.

Effective Spread

The transaction cost is usually measured using the bid-ask spread. However, when that measure is used, the transaction cost of the investor who orders the bid and the transaction cost of 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 the effective spread (Z_t,). First, the following quoted spread, Q_t , is used[3].

$$Q_t = (a_t + b_t)/2 \qquad (4)$$

Therein, 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 transaction execution cost when transactions are done within the spread.

The effective spread (Z_t,) is formulated as follows.

$$Z_t = \left|P_t - Q_t\right| \qquad (5)$$

In that equation, P_t denotes the contract value and Q_t represents the quoted spread, 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.

In the following equation, the information effect of the spread is analyzed: *Effective Spread* (t) denotes the proxy of the spread[4].

$$R_t = a_0 + a_1 h_t + \phi EffectiveSpread_t + e_t \quad (6)$$

Here, if coefficient ϕ is significant, then the intraday pattern of the spread explains the intraday pattern of the return. The expected sign of the coefficient is negative. The return is expected to increase as the spread narrows.

Finally, we estimate the EGARCH (1, 1)-M econometric specification including two factors (volume and effective spread) in the mean equation.

$$R_t = a_0 + a_1 h_t + \theta Volume_t + \phi EffectiveSpread_t + e_t \quad (7)$$

The expected signs of the coefficient of θ and ϕ are, respectively, a minus and a plus. The volume and the spread explain the intraday pattern of the return if coefficients θ and ϕ are statistically significant. The negative coefficient of θ represents that the return decreases as the volume increases. The negative coefficient of ϕ signifies the return decrease as the spread widens.

Expected sign of each coefficient

	a_0	a_1	θ	ϕ
Eq. (1), (3), (6), (7)	±	+	−	−

3. Data and Statistics

Data

This section presents a description of the data used for analyses. 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 each business day: the total samples are 104,370[5].

The data are obtained from "KIKKEI NEEDS (Tick Saiken Sakimono Option)". The return on JGB futures is calculated for each interval. First, the contract price data are made. The contract price of the interval immediately prior is used when transactions are not contracted at a certain interval and the contract price has not been described in the book. Therefore, new information has not been brought to the market. The quotes are similar. In addition, for the quotes, we selected the combination of the bid price and the ask price immediately before the transaction is made. According to Huang and Stoll (1996), the effective spread is used for this study.

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

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 and when the market closes.

At opening, all quotes (orders) before the contract price are recorded in the order book. 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 during transaction times other than opening or 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.

Statistics

The correlation between the volatility and the volume is weak, although the respective correlations of time series data are presented in Table 2. Furthermore, the correlation of volatility and the three spreads is weak. The correlation of the volume to the spread is also weak. A problem of multicollinearity would probably not arise even if they were used simultaneously for estimation.

Moreover, when R (return) was checked using the Box-Jenkins method, the autocorrelation was apparent 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.

4. Empirical Results

The results produced the EGARCH

Table 1 Statistics of variables

	Price	Return	Volume	Effective Spread
Mean	13994.972	−0.000038	14.442608	0.631211076
Standard deviation	265.72857	0.0153607	126.58615	0.71528027
Variance	70611.673	0.00023595	16024.054	0.511625865
Kurtosis	−1.039902	311.625424	860.91898	1505.778667
Skewness	0.4178135	−3.1118635	24.602158	30.45679327
Observations	104370	104370	104370	104370

Table 2 Correlation

	Price	Return	Volume	Effective Spread
Price	1			
Return	0.0037	1		
Volume	0.0022	-0.0164	1	
Spread	-0.0996	0.0292	0.1768	
Quoted Spread	-0.0996	0.0292	0.1768	
Effective Spread	-0.1077	-0.0409	0.2102	1

(1,1)-M model (eq. (1)) expressed in Table 3. The intraday pattern of the volatility explains the intraday pattern of the return. Coefficient a_1 was significant and negative, contrary to our expectation. Coefficient d was found to be negative and statistically significant, thereby verifying the asymmetry of volatility. Moreover, coefficient b measures the volatility persistence: this is positive and significant. The volatility crusting is verified too. These facts indicate that the effect of a shock lasts for some time, but the direction of the effect differs according to characteristics of the shock.

In Table 4, the coefficient θ is significant and negative when the volume is an explanatory variable in the EGARCH (1, 1)-M model (eq. (3)). This result implies that risk decreases as the volume increases. Moreover, the asymmetry of volatility and the volatility crusting are verified.

In Table 5, the coefficient (ϕ) of the effective spread is negative and significant in the EGARCH (1, 1)-M model (eq.(6)). The return is expected to decrease as the effective spread widens. Moreover, the asymmetry of volatility and the volatility crusting are verified. Those results correspond to the results presented in Tables 3 and 4.

In Table 6, the coefficient θ of the volume is significant and positive in EGARCH (1, 1)-M when the volume and the effective spread are added to eq. (1)[6]. The correlation between the return and the volume is positive, which implies that risk increases as the volume increases. The coefficient ϕ of the effective spread is significant and negative in the conditional mean eq.(7)[7]. This result shows that the return decreases as the spread widens. In a word, the bigger the transaction cost, the lesser the return. This result implies that risk decreases as the effective spread widens. As the coefficient θ and ϕ show, a tendency toward countervailing change prevails between the intraday patterns of the volume and the spread. Moreover, volatility crusting is verified, the effect of shocks continues over a long term.

From the estimation results presented above, the coefficient θ of the volume is negative. The correlation between the return and the volume is negative. The intraday pattern of the volatility and the intraday pattern of the volume change are in opposite directions. The coefficient of the spread (effective spread) is negative. The correlation between the return and the spread is negative. The intraday pattern of the spread (effective spread) and that of the volatility change in opposite directions. This relation shows that as the spread widens, volatility decreases.

Results described above show that, with regard to the persistence of volatility, the persistence is remarkable. The effect of ARCH and the effect of GARCH are significant; also, the effects of shocks continue over a long term. Regarding the asymmetric volatility, this was confirmed significantly. Market participants react more strongly to unfavorable information than they do to favorable information. It is inferred that this phenomenon means that the market participants have a sentiment related to the investment.

Table 3 Estimation EGARCH (1,1) -M equation (1)

	EGARCH-M	
Variable	Coeff.	Signif.
1. a_0	-0.0035	0
2. a_1	-0.0003	0
3. c	-1.2701	0
4. a	0.5492	0
5. b	0.8856	0
6. d	-0.0566	0
Log Likelihood	313156.3483	

*Signif. = P value

Table 4 Volume equation (3)

	EGARCH-M	
Variable	Coeff.	Signif.
1. a_0	-0.0035	0
2. a_1	-0.0003	0
3. θ	-0.0000007	0
4. c	-1.2774	0
5. a	0.5518	0
6. b	0.8849	0
7. d	-0.0576	0
Log Likelihood	313159.8322	

*θ = coefficient of the Volume.

Table 5 Effective Spread equation (6)

Variable	EGARCH-M Coeff.	Signif.
1. a_0	0.0021	0
2. a_1	-2.80E-06	0
3. ϕ (ES)	-0.0042	0
4. c	-1.1154	0
5. a	0.5139	0
6. b	0.9028	0
7. d	0.0210	0
Log Likelihood	315295.5109	

*ϕ (ES) =coefficient of the Effective Spread

Table 6 Volume and Effective Spread equation (7)

Variable	EGARCH-M Coeff.	Signif.
1. a_0	0.0025	0
2. a_1	0.00003	0
3. θ	4.94E-06	0
4. ϕ (ES)	-0.0046	0
5. c	-1.0831	0
6. a	0.5080	0
7. b	0.9063	0
8. d	0.0270	0
Log Likelihood	315440.4607	

*θ = coefficient of the Volume,
ϕ (ES) = coefficient of the Effective Spread

5. Conclusion

This paper presents an examination of empirical relations among return, volatility, and liquidity of the Japanese Government Bond (JGB) Futures market of the Tokyo Stock Exchange (TSE). The purpose is to measure the volatility and to reveal the relation of the return, the volume, and the spread. To this end, it is necessary to verify relations in the intraday pattern of the return and each intraday pattern of the volatility, the volume, and the spread. We estimated the EGARCH (1, 1)-M model.

Results of estimation reveal that an inverse relation exists between the intraday pattern of the return and the intraday pattern of the volume in some models. The negative coefficient of the volume signifies that the return decreases as the volume increases. This result implies that risk decreases as the volume increases. Moreover, the relation between the return and the spread is shown to change in the opposite direction. The negative coefficient of the spread signifies that the return decreases as the spread widens. This result implies that risk decreases as the effective spread increases. It is expected that the risk decreases 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.

Regarding the persistence of volatility, the effect of ARCH and the effect of GARCH are significant. Moreover, the effect of shocks persists over a long term. Regarding the asymmetric volatility, this is confirmed significantly. Market participants react more strongly to unfavorable information than favorable information. It is inferred that this phenomenon demonstrates that the market participants have some sentiment related to the investment. Therefore, irrationality (illogical behavior) exists in these investors' transaction behavior.

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1 See Amifud, Mendelson and Pedersen (2005).

2 As Bolleslev (1986), and Campbell, Lo, and MacKinlay (1997) report, the GARCH (1,1) model fulfills the principle of the saving and can capture the effect of ARCH of higher order. The ARCH-M model (Engle, Lilien, and Robins (1987)) generalizes the ARCH model by allowing a function of the variance to enter the regression function itself.

3 This quoted spread was used to illustrate which investor causes the transaction cost: the bid side or the ask side.

4 We use spread of three kinds (the spread, quoted spread, and effective spread). However, in this paper, we report the empirical result of the effective spread only.

5 However, the market is open only during the respective morning sessions on December 30, 2003 and January 5, 2004. Therefore, these two transaction days were excluded from the analyses. Moreover, one interval is one minute. For instance, in the first session, intervals are 9:00-9:01, 9:01-9:02, … , and 10:59-11:00.

6 When the volume and the spread or the quoted spread are added to eq. (1), the coefficient of the volume is significant and negative in EGARCH (1, 1)-M model. This result implies that the risk decreases as the volume increases. However, these results are not presented in the table.

7 The coefficients ϕ of the spread and quoted spread are significant and positive in the conditional mean eqs. (3) and (6). However, these results are not presented in the table.

［Abstract］

Empirical Relation among Return, Volatility and Liquidity of the JGB Futures： the EGARCH-M Model

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This paper presents an examination of the empirical relation among return, volatility, and liquidity of the Japanese Government Bond (JGB) Futures market of the Tokyo Stock Exchange (TSE). Using the EGARCH-M model, the existence of volatility clustering and the asymmetry of volatility in the JGB Futures market was observed. Moreover, the results show a negative correlation between the intraday pattern of return and that of the trade volume. Risk decreases as the volume increases. The return and the spread (effective spread) change in opposite directions. The return is expected to increase as the spread narrows. Risk decreases as the investor's transaction cost increases.

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