INTRADAY RETURN DYNAMICS BETWEEN THE CASH AND THE FUTURES MARKETS IN JAPAN

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INTRODUCTION

A growing body of literature is devoted to the analysis of the intraday relationship between futures and stock index returns in the U.S. market. Stoll and Whaley (1990a) found that futures returns significantly lead stock returns even after adjusting for infrequent trading bias. However, stock returns weakly predict futures returns. They interpreted this evidence as meaning that the futures market reflects new information

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more quickly than the stock market. Several studies have investigated why futures lead stock index prices. Chan (1992) investigated the effect of short sales constraints, differential trading volume, and market-wide or firm-specific news events on intraday relationships.[1] Since firm-specific information is diversifiable and market-wide information is systematic, the discovery of market-wide information is more important, so he hypothesized that the feedback from the futures market into the stock market is larger than the reverse.

Chan, Chan, and Karolyi (1991) extended the studies of lead–lag relationships between the stock and futures markets by allowing the volatility of price changes as well as price changes themselves to interact across two markets. Chan et al. utilized a bivariate generalized autoregressive conditional heteroskedastic (GARCH) model and documented that price innovation in either the stock or futures market may be able to predict the arrival of new information in the other market. Their results do not support previous findings concerning intermarket dependence between stock and futures prices. Price innovations that originate in either the stock or futures markets can predict the future volatility in the other market.

Analysis of the intraday relationship between stock index and stock index futures in Japan is very limited.[2] The only study that utilizes transactions data in Japan is by Lim (1992). He analyzed the Nikkei Stock Average (NSA) stock/futures relationship using transactions data obtained from the Singapore International Monetary Exchange (SIMEX). However, Lim's study focused on the transactions data of only several trading days on the SIMEX. Lim found no lead–lag relationship between the NSA and the NSA futures traded on the SIMEX.

This study investigates the intertemporal relationship between the NSA index and NSA index futures using minute-by-minute transactions data from the Osaka Securities Exchange (OSE). The sample is much larger than Lim's. Furthermore, trading volume on the SIMEX has decreased dramatically since the introduction of NSA futures on the

[1]Black (1975), Anthony (1988), and Miller (1990) also argued that market frictions such as transaction costs and capital requirements may be reasons why some investors trade in the derivative markets rather than in the stock markets.

[2]Several studies have examined the relationship between the NSA in Tokyo and futures trading in Osaka and in Singapore. Brenner, Subrahmanyam, and Uno (1989a) documented the existence of arbitrage opportunities using daily data from the TSE and the Singapore International Monetary Exchange (SIMEX). Brenner, Subrahmanyam, and Uno (1989b) also examined the behavior of the daily prices of both the Osaka Kabusaki 50 and the NSA futures in the SIMEX.

OSE.[3] Therefore, this analysis, using data that reflects the increased trading volume from the OSE, should shed additional light on the Nikkei cash–futures relationship.

The database covers the period from March, 1989 to February, 1991. This time period is particularly interesting because during that time period the OSE introduced stricter measures to stabilize the underlying stock prices.[4] The first stabilization attempt was made on August 24, 1990, when the OSE raised the margin from 9% to 15%, reduced the price range for special quotations from 90 yen to 50 yen, and extended the waiting time for soliciting counter orders from three minutes to six minutes.[5]

Special price quotations refer to bid quotes or asked quotes that are set by the stock exchange to solicit counter orders in times of major order imbalance.[6] The Japanese stock exchanges leave these special price quotations, in place for a certain time period to maintain some continuity in the price change series. The price following a special price quote must fall within a certain range.[7] In the stock market, the price range is between 1% and 2% of the stock price. The price range for NSA futures, on the other hand, is set at less than 0.5% of the index level. This study's sample allows an examination of how the special quotation measure affects both stock and futures trading. This study also seeks to determine whether the introduction of stricter measures really reduces stock market volatility and/or if the stricter measures alter the dynamics of the volatility patterns. Finally, the study investigates how quickly each market absorbs new information before and after the stricter measures are introduced.

[3]During the sample period of this study, the trading volume on the SIMEX is less than 10% of the trading volume on the OSE. However, the SIMEX has caught up with the OSE in terms of trading volume since the OSE introduced stricter measures. (This is discussed later.)

[4]The Ministry of Finance informally asked the OSE to introduce the stricter measures to reduce the effect of futures trading on cash market volatility.

[5]The margin was raised from 15% to 20% on January 31, 1991. The margin was again raised to 25% on June 27, 1991. The waiting time was reduced from six minutes to five minutes. The price range for special price quotations was reduced from 50 yen to 30 yen. Finally, on December 18, 1991, the OSE raised the margin from 25% to 30%.

[6]See Hamao and Hasbrouck (1993) and Lehmann and Modest (1994a, 1994b) for more details.

[7]The price range is 90 yen when the futures price level is between 20,000 yen and 30,000 yen, and 120 yen when the level is between 30,000 yen and 40,000 yen. On the other hand, the price range for stock is 200 yen when the stock price is between 10,000 yen and 30,000 yen, and 300 yen when the price is between 30,000 yen and 50,000 yen.

TIME SERIES PROPERTIES OF JAPANESE INTRADAY DATA

Data

The data used in this study are from the OSE. The data set contains the time of transaction and the price for every futures transaction, as well as the NSA index level each time it is computed and announced during the period from March 1, 1989 to February 26, 1991. There are three distinct time periods in the sample. The first period includes the year 1989 (bull market).[8] The second period includes the year 1990 until the introduction of the stricter measures on August 24, 1990 (bear market). The third period begins after the introduction of the stricter measures and continues to March, 1991 (bear market).

The NSA index is computed once a minute; the NSA futures price is available when the trade takes place during the session.[9] Therefore, unlike the stock index, observation of the futures price series is not uniformly spaced in time. Like S&P 500 futures, NSA futures have a quarterly expiration cycle (March, June, September, and December). During the sample period, only nearby contracts for NSA futures (excluding the expiration month) are used because nearby contracts are usually the most actively traded. Several days before reaching the expiration month, the trading volume of nearby contracts substantially decreases because the next nearby contracts become more frequently traded in the market. Therefore, the period during which the trading volume of the next nearby contracts exceeds that of the nearby contracts is also excluded. As a result, approximately a three-month period of time series data is obtained for each contract.

The intraday price series are partitioned into five-minute intervals to generate a time series of intraday rates of return. The returns for the futures (F_t) and the cash index (C_t) are defined as $R_{f,t} = 100 \cdot \ln(F_t/F_{t-1})$ and $R_{c,t} = 100 \cdot \ln(C_t/C_{t-1})$, respectively. The first five minutes of each trading session are excluded because the index

[8]The reason for this partition is the change in stock market conditions. By the end of the first period, the stock market had hit its peak. Since the beginning of the second period, the stock market has been declining.

[9]The morning session (the afternoon session) started at 9 AM (1 PM) and ended at 11 AM (3 PM) on the Tokyo Stock Exchange (TSE) during the sample period. The OSE changed its futures trading hours during the sample period. Trading hours were initially set from 9:00 AM to 11:05 AM and from 1:00 PM to 3:15 PM; this timetable continued until the end of September, 1989. From the beginning of October, 1989 until April 26, 1991, trading hours were from 9:00 AM to 11:00 AM and from 1:00 PM to 3:10 PM.

values for the beginning period of each session are computed using the closing stock prices from the previous day.[10] The intraday, overnight, and lunchtime periods are based upon the stock market trading hour.[11]

The average daily futures trading volume, the distribution of futures trading volume, and nontrading probabilities for all NSA futures contracts are presented in Table I. Nontrading probability is the proportion of intervals in which no trades occur within the five-minute intraday intervals. Table I shows that trading volume on the NSA futures grew dramatically even after 1990. However, the nontrading probability in the five-minute interval also increased after 1990. There is a serious infrequent trading problem for the December 1990 contract. Approximately 43% of intraday five-minute intervals do not contain any trades for the December 1990 contract.[12]

This finding contrasts with that of Chan (1992). The nontrading probability of S&P 500 index futures in the five-minute interval is zero for his three-year sample period. Apparently, the NSA futures are not traded as frequently as S&P 500 Futures. Therefore, the infrequent trading of the NSA futures should be taken into account before the lead–lag relationship between the two markets is examined. The intraday stock index returns are excluded when the futures intraday returns are not observed at the same time.

Furthermore, continuous observations are necessary to examine the lead–lag relationship. Therefore, if the intraday futures returns are not continuous (that is, existing for at least seven consecutive five-minute intervals), then both the intraday stock index and futures returns are excluded. In other words, a maximum of six lags can be used for this sample. As a result, the number of usable observations for the sample dramatically decreases, especially in 1990.[13]

[10]According to Uno (1994), all NSA stocks are executed within the first five minutes, on average.

[11]The first day and the last day of the year are excluded because both the TSE and the OSE are open for only half a day on those days. Furthermore, October 2, 1990 is excluded from this sample because there was no futures trading on that day.

[12]The intraday trading volume increased dramatically in 1990 and 1991. Consequently, both the overnight and the lunchtime trading volume declined in 1990 and 1991. Since the opening trade is rarely executed within the first five minutes of the morning session in late 1990 and 1991, a majority of futures opening trades are included in the intraday trading volume.

[13]Another factor which affects the sample size is the lunchtime break in Japanese markets. After excluding the first five-minute interval, at maximum, 23 five-minute intervals can be used for both the morning and afternoon sessions. In other words, at maximum, 22 lags can be used, even if there was no infrequency in futures trades for all five-minute intervals. Due to the limited availability of five-minute intraday returns in Japan, this study focuses only on the five-minute intraday returns that are observed over a minimum of seven consecutive time intervals.

TABLE I

Trading Volume, Nontrading Probability of Nikkei Stock Average Futures during the Period, March, 1989 through February, 1991

	Expiration Month of Futures Contract							
	1989			*1990*				*1991*
	June	*September*	*December*	*March*	*June*	*September*	*December*	*March*
	Number of Trading Days							
	53	*63*	*58*	*56*	*58*	*60*	*57*	*45*
Daily trading volume	18,395	20,659	23,423	29,401	45,564	55,405	53,475	69,293
Intraday period[a]	33.1%[b]	32.3%	34.1%	51.8%	51.0%	54. 3%	84.4%	76.8%
Lunchtime period[c]	31.2%	31.7%	29.0%	23.3%	25.8%	22. 9%	8.1%	10.8%
Overnight period[d]	35.7%	36.0%	36.9%	24.9%	23.3%	22. 8%	7.6%	12.4%
Nontrading probability[c]	0.49%	0.38%	0.52%	4.35%	8.88%	9.13%	43.17%	14.83%

[a]Trading volume is computed by summing the volume during the two periods 9:05–11:00 AM and 1:05–3:00 PM.

[b]Each number corresponds to the ratio between the trading volume in each period and the overall trading volume for each contract.

[c]Trading volume is computed by summing the volume during the period 11:00 AM–11:05 PM.

[d]Trading volume is computed by summing the volume during the period 3:00 PM–9:05 AM (following day).

[e]Nontrading probability is the proportion of five-minute intervals in the intraday period in which there is no trade to the total number of five-minute intraday intervals.

The lead–lag relationship between the two markets for three distinct time periods is now analyzed using the above matched pair intraday cash and futures returns.

Summary Statistics

The summary statistics of the matched pair five-minute intraday returns of the NSA stock and futures are presented in Table II. The statistics include sample size, mean, standard deviation, skewness, kurtosis, maximum, and minimum of intraday returns for three distinct time periods. Notably, the standard deviation of both stock and futures returns increase through the sample period. The stricter measures introduced in August, 1990 do not seem to have reduced the volatility of the stock market during the third period. The stricter measures, however, reduce the trading frequency of futures dramatically, as shown in Table I.

The variance ratio (futures/stock) is also interesting. If futures prices are as informative as stock prices, the variance ratio should be

TABLE II

Summary Statistics and Autocorrelations for Intraday Five-Minute Returns of the Nikkei Stock Average (NSA) and NSA Futures during the Three Distinct Periods

	Stock Index			*Stock Index Futures*		
	1st Period	*2nd Period*	*3rd Period*	*1st Period*	*2nd Period*	*3rd Period*
Sample size	6424	5671	1664	6424	5671	1664
Mean (%)	−0.0025	−0.0020	0.0002	0.0009	−0.0008	−0.0014
Standard deviation	0.0540	0.0928	0.1270	0.0457	0.1077	0.1230
Skewness	0.8732	0.5445	0.8932	−0.0158	−0.0384	−0.0285
Kutorsis	3.5529	5.5094	2.5160	2.4568	2.8486	0.1379
Maximum	0.3486	0.6287	0.7304	0.3102	0.5708	0.4297
Minimum	−0.2491	−0.6032	−0.4589	−0.2763	−0.5902	−0.4342
Autocorrelations						
			$\rho(r_t, r_{t-k})$			
$k = 1$	0.1111[a]	0.1841[a]	0.0976[a]	0.0299	0.1021[a]	0.0350
2	0.0298	0.0426[a]	−0.0273	−0.0127	0.0551[a]	0.0336
3	0.0255	0.0376	−0.0536	0.0363	−0.0016	0.0174
4	0.0294	0.0140	0.0246	0.0298	−0.0257	−0.0143
			$\rho(r_{t^2}, r_{t-k^2})$			
$k = 1$	0.0808[a]	0.0909[a]	0.0533	0.1302[a]	0.2488[a]	0.0848[a]
2	0.0391	0.0984[a]	0.0079	0.1008[a]	0.2405[a]	0.1246[a]
3	0.0296	0.0908[a]	0.0076	0.1230[a]	0.2060[a]	0.0916[a]
4	0.0279	0.0550[a]	0.0100	0.1014[a]	0.2210[a]	0.0627[a]

[a]Significant at the 0.1% level.

The first period contains the observations from March 1 to December 28, 1989. The second period contains the observations from January 4 to August 23, 1990. The third period contains the observations from September 1 to February 26, 1991.

close to one. If the stock (futures) market is noisier than the futures (stock) market, the variance ratio must be smaller (greater) than one. MacKinlay and Ramaswamy (1988) examined the relative volatility of S&P 500 index futures and index returns and found that futures returns are significantly more volatile than stock returns. They found a ratio of 1.56 for 15-minute returns. Grünbichler, Longstaff, and Schwartz (1994) reported a ratio of 1.19 for 15-minute returns in the German DAX index and index futures. Referring to the smaller German variance ratio, they concluded that screen-traded futures prices in the DAX index futures market are less noisy than floor-traded futures prices in the S&P 500 index futures market.

The analyses of this study show that the variance ratios for the first period, the second period, and the third period are 0.717, 1.347, and 0.937, respectively, which are all less than the comparable ratio of 1.56 for the U.S. The NSA futures are traded on the screen, but more than half of the stocks included in the NSA index are traded on the floor. These results are consistent with Grünbichler, Longstaff and Schwartz (1994). Screen-traded futures prices in Japan seem to be less noisy than floor-traded futures prices in the U.S.[14]

Autocorrelation coefficients (up to the fifth order) for the matched pair intraday cash and futures returns are presented in Table II. The autocorrelations of cash returns are significantly positive for the first five minutes for the first and the third periods and up to the second five-minute interval for the second period. The autocorrelations of futures returns are insignificant and small for the first and the third periods and significantly positive but smaller than stock autocorrelations for the second period. The significant positive autocorrelation for the second period futures returns is striking. These results indicate that adjustment for linear dependence is necessary for both cash and futures returns.

Autocorrelation coefficients for squared returns are computed and displayed in Table II. The results show nonlinear dependence in the intraday stock and futures returns for all sample periods except the cash returns for the third period. The insignificant third-period cash returns is puzzling. These results imply that a model for the return-generating processes in the stock and futures markets accounting for higher-order dependence in the returns is appropriate.

[14]The results of this study cannot be compared directly to results of U.S. and German studies because the intraday interval is different. As a result, one must be cautious about making any interpretation.

EMPIRICAL RESULTS

Lead–Lag Relationship of Intraday Returns

Stoll and Whaley (1990a) used an ARMA process to purge the effects of infrequent trading and extract the return innovations to proxy for true index returns. Miller, Muthuswamy, and Whaley (1994) used the modified AR(1) model to adjust for infrequent trading and showed that the negative serial correlation of the basis change is partly reflected by statistical illusion. Along the same lines as Miller et al., this study uses an AR(1) process to purge the effects of nonsynchronous trading of cash returns.[15]

Table II indicates that linear dependence exists in the intraday returns. The Schwartz criterion is used to determine the length of the filter. The AR(1) process should be sufficient for correcting the linear dependence of the cash returns for all three periods and the futures returns for the second period. The return innovations of the NSA are regressed on the contemporaneous futures returns for the first and the third periods, and on the return innovations of the NSA futures for the second period, the first four lagged futures returns and the first two leading cash returns are regressed.[16]

For the first and the third periods the regression is:

$$\epsilon_{c,t} = \alpha + \sum_{i=-4}^{2} \beta_i R_{f,t+i} + u_t \tag{1}$$

and for the second period:

$$\epsilon_{c,t} = \alpha + \sum_{i=-4}^{2} \beta_i \epsilon_{f,t+i} + u_t \tag{2}$$

where $\varepsilon_{c,t}$ is the return innovations of the cash, $\varepsilon_{f,t}$ is the return innovations of the futures, and $R_{f,t}$ is the futures return. These specifications, however, do not consider the dynamics of the conditional variances. Previous evidence suggests that the return innovations are likely to be

[15]However, it is possible that asynchronous trading might be time varying so that its effect would not be captured by an AR(1) process. Therefore, the results may be spuriously induced by an asynchronous trading problem. To gauge the degree of asynchronous trading in the index, the autocorrelogram is computed for different times of the day: the first 30 minutes, the middle 30 minutes, and the last 30 minutes. The results do not support the hypothesis that the effect is time varying.

[16]Preliminary analysis shows that cash leads futures weakly and futures lead cash strongly. Therefore, a longer lag is used for the futures returns than for the cash returns.

heteroskedastic.[17] Since heteroskedasticity leads to inconsistent estimates of standard errors, all of the t statistics for the coefficients are adjusted by using the Generalized Method of Moments (GMM).

Table III reports the results from estimating the lead–lag regression. It is apparent that the futures returns lead the cash returns strongly and the cash returns weakly lead the futures returns. These results are consistent with the major U.S. findings for the first two periods. The futures returns lead the cash returns up to 20 minutes.[18] Alternatively, futures returns weakly lead cash returns by five minutes. These results are consistent with the hypothesis that the market-wide new information disseminates in the futures markets before the stock markets.

In contrast to the first and the second periods, futures returns lead cash returns only up to five minutes for the third period. Cash returns do not lead the futures returns. The stricter measures appear to have reduced the speed of information dissemination in the futures markets. The market structure may have changed because of the stricter measures.

TABLE III

Parameter Estimates from Regression of Nikkei Stock Average (NSA) Return Innovations from an AR(1) Model on Lagged, Contemporaneous, and Leading NSA Futures Returns (or NSA Futures Return Innovations)

Parameters	*1st Period*	*2nd Period*	*3rd Period*
α	−0.0005 (−0.98)	−0.0012 (−1.55)	0.0011 (0.53)
β_2	−0.0148 (−1.16)	−0.0342 (−2.83)	−0.0380 (−1.42)
β_1	0.1344 (9.89[a])	0.0491 (4.02[a])	0.0487 (1.76)
β_0	0.4539 (28.24[a])	0.3399 (25.87[a])	0.3693 (15.09[a])
β_{-1}	0.0935 (6.94[a])	0.2477 (18.52[a])	0.3327 (14.12[a])
β_{-2}	0.1240 (9.10[a])	0.0923 (7.81[a])	0.0567 (2.41)
β_{-3}	0.0572 (4.23[a])	0.0447 (3.57[a])	0.0307 (1.19)
β_{-4}	0.0602 (4.50[a])	0.0429 (3.69[a])	0.0438 (2.00)

[a]Significant at the 0.1% level.

For the first and the third periods:

$$\epsilon_{c,t} = \alpha + \sum_{i=-4}^{2} \beta_i R_{f,t+i} + u_t$$

For the second period:

$$\epsilon_{c,t} = \alpha + \sum_{i=-4}^{2} \beta_i \epsilon_{f,t+i} + u_t$$

[17]Similar patterns are observed for autocorrelation coefficients of the squared cash and futures return innovations.

[18]The coefficients of the fifth and the sixth lagged futures returns without taking any leading futures returns are examined. Both the fifth and the sixth coefficients are statistically insignificant.

Lead–Lag Relationship of Intraday Volatility

The ARCH family of models incorporating time variation in the volatility of intraday stock and futures returns is used to examine the intermarket dependence of the returns and return volatility between the two markets. A number of studies in the U.S. indicates that the ARCH family of models reasonably captures the time variation in the volatility of daily and monthly stock returns.[19] Tokunaga, Iihara and Kato (1993) suggest that ARCH effects are also present in Japanese daily stock returns.

In conjunction with an AR(1) process, the bivariate GARCH(1,1) model is utilized to capture the second-order time dependence of both cash and futures returns.[20] This model provides an opportunity to examine the intraday relationship between returns and return volatility in the cash and futures markets in the same context as Chan et al.

Such a model for the joint processes generating the cash and futures returns is given below.

$$R_t = \phi_0 + \phi_1 R_{t-1} + \epsilon_t$$
$$\epsilon_t | \Phi_{t-1} \sim \mathrm{BVN}(0, H_t) \tag{3}$$

$$\begin{bmatrix} h_{cc,t} \\ h_{ff,t} \end{bmatrix} = A_0 + A_1 \begin{bmatrix} \varepsilon^2_{cc,t-1} \\ \varepsilon^2_{ff,t-1} \end{bmatrix} + B \begin{bmatrix} h_{cc,t-1} \\ h_{ff,t-1} \end{bmatrix} \tag{4}$$

$$h_{cf,t} = \rho\left(h_{cc,t} h_{ff,t}\right)^{1/2} \tag{5}$$

Where the return vector for the cash and futures series is given by $R_t = [r_{ct}, r_{ft}]$, the residual vectors by $\epsilon_t = [\epsilon_{ct}, \epsilon_{ft}]$, and conditional covariance matrix by H_t, where $\{H_t\} = h_{ij,t}$ for $i, j = c, f$. The parameter vectors and matrices are defined as $\phi_0 = [\phi_{c0}, \phi_{f0}]$, $A_0 = [\alpha_c, \alpha_f]$, and $\{\phi_1\}_{ij} = \phi_{ij1}, \{A_1\}_{ij} = \alpha_{ij}, \{B\}_{ij} = \beta_{ij}$ all for $i, j = c, f$. Φ_{t-1} is the set of information available at time $t - 1$. Equation (5) implies a bivariate time series model with a constant conditional correlation, although this model allows time-varying conditional variances and covariances. From eqs. (3)–(5), the conditional log likelihood function $L(\theta)$ for a sample

[19]Bollerslev, Chou, and Kroner (1993) summarize the studies concerning the application of ARCH family models to the major issues in finance.

[20]Chan et al. (1991) employed the bivariate AR(1)–GARCH(1,3) model. A variety of the bivariate ARCH type models, including a time-varying correlation coefficient model, is applied also to the data of this study. The results remain qualitatively unchanged.

of T observations has the following form:

$$L(\theta) = \sum_{t=1}^{T} l_t(\theta) \tag{6}$$

$$l_t(\theta) = -\log 2\pi - 1/2 \log |H_t(\theta)| - 1/2\epsilon_t'(\theta)H_t^{-1}(\theta)\varepsilon_t(\theta) \tag{7}$$

where θ denotes the vector of all the unknown parameters. Numerical maximization of eqs. (6) and (7) yields the maximum likelihood estimates with asymptotic standard errors.

Table IV presents the results of fitting the bivariate GARCH model to the intraday NSA index and futures returns. Highly significant positive

TABLE IV

Estimates from Bivariate Generalized Autoregressive Conditional Heteroskedastic (GARCH) Model of Intraday Returns of the Nikkei Stock Average (NSA) and the NSA Futures during the Period March, 1989 through August, 1990

	1st Period	*2nd Period*	*3rd Period*
ϕ_{c0}	−0.0020 (−3.26)	−0.0120 (−1.22)	0.0088 (0.29)
ϕ_{f0}	0.0166 (3.11)	0.0058 (0.60)	−0.0135 (−0.49)
ϕ_{cc1}	0.0430 (3.05)	0.0043 (0.30)	−0.0401 (−1.50)
ϕ_{cf1}	0.1311 (8.12[a])	0.3059 (24.80[a])	0.3725 (13.40[a])
ϕ_{fc1}	0.1116 (10.80[a])	0.0545 (4.18[a])	0.0769 (3.21)
ϕ_{ff1}	−0.0455 (−3.45[a])	0.0325 (2.64)	0.0018 (0.07)
α_{c0}	0.0335 (10.90[a])	0.0739 (12.90[a])	0.2728 (2.56)
α_{f0}	0.0065 (2.83)	0.0188 (3.19)	−0.0488 (−0.55)
α_{cc1}	0.1259 (15.50[a])	0.1022 (16.60[a])	0.0734 (3.25)
α_{cf1}	0.0369 (5.31[a])	0.0901 (16.80[a])	0.0623 (3.19)
α_{fc1}	−0.0007 (−0.21)	0.0147 (3.15)	0.0015 (0.91)
α_{ff1}	0.1062 (14.60[a])	0.2278 (20.10[a])	0.0788 (4.88[a])
β_{cc1}	0.2804 (49.00[a])	0.7455 (43.60[a])	0.5279 (3.31[a])
β_{cf1}	−0.0279 (−2.31)	−0.0381 (−5.21[a])	0.1625 (1.54)
β_{fc1}	0.0001 (0.02)	−0.0153 (−0.84)	−0.0091 (−0.06)
β_{ff1}	0.8734 (58.50[a])	0.7918 (66.70[a])	0.9655 (10.90[a])
ρ	0.4320 (44.30[a])	0.4242 (41.00[a])	0.3967 (18.50[a])
$\log L(\theta)$	−8021.81	−13813.46	−5161.57

[a]Significant at the 0.1% level.

The conditional log likelihood function to be maximized is given in eqs. (6) and (7). The values in parentheses are asymptotic t statistics.

$$\begin{bmatrix} r_{ct} \\ r_{ft} \end{bmatrix} = \begin{bmatrix} \phi_{c0} \\ \phi_{f0} \end{bmatrix} + \begin{bmatrix} \phi_{cc1} \phi_{fc1} \\ \phi_{cf1} \phi_{ff1} \end{bmatrix} \begin{bmatrix} r_{ct-1} \\ r_{ft-1} \end{bmatrix} + \varepsilon_t$$

$$\varepsilon_t|\Phi_{t-1} \sim \mathrm{BVN}(0, H_t)$$

$$\begin{bmatrix} h_{cc,t} \\ h_{ff,t} \end{bmatrix} = \begin{bmatrix} \alpha_{c0} \\ \alpha_{f0} \end{bmatrix} + \begin{bmatrix} \alpha_{cc1} \alpha_{cf1} \\ \alpha_{fc1} \alpha_{ff1} \end{bmatrix} \begin{bmatrix} \varepsilon^2_{cc,t-1} \\ \varepsilon^2_{ff,t-1} \end{bmatrix} + \begin{bmatrix} \beta_{cc1} \beta_{cf1} \\ \beta_{fc1} \beta_{ff1} \end{bmatrix} \begin{bmatrix} h_{cc,t-1} \\ h_{ff,t-1} \end{bmatrix}$$

$$h_{cf,t} = \rho(h_{cc,t} h_{ff,t})^{1/2}$$

coefficients, (ϕ_{cf1}) for all three periods and (ϕ_{fc1}) for the first two periods, are consistent with previous findings.

The coefficients that measure the cross-market impact of returns shocks on the volatility are interesting. α_{cf1}, which conveys the past futures return innovations to the conditional variance of the cash market, is significant for the first and the second periods and becomes insignificant for the third period. Alternatively, α_{fc1}, which conveys the past cash return innovations to the conditional variance of the futures market, is insignificant for all three periods. These results indicate that the past shocks of futures returns affect current stock return volatility before the introduction of the stricter measures. On the other hand, the stock return shocks do not have any significant impact on futures return volatility. This is not consistent with the evidence presented by Chan et al. The results of this study show that the information flow between the two markets is not bidirectional but unidirectional, from the futures to the stock market, for the first and the second periods. However, during the third period, some of the predictability from the futures to cash returns appears to have diminished. In a sense, then the Ministry of Finance and the OSE achieved their objective of reducing the influence of futures market trading on the underlying cash market's volatility.

The coefficients (α_{ff}) are also significant for all three periods, which implies that the past futures return shock affects current futures returns volatility. The coefficients (α_{cc}) are significant for the first two periods, which is consistent with the findings in the previous section.

The parameters which measure the linear dependence of conditional volatilities, β_{cc} and β_{ff}, are also interesting. The coefficients are significantly positive for all three periods. The conditional volatility in the previous period affects conditional volatility in the current period for both cash and futures markets. On the other hand, the coefficients (β_{cf} and β_{fc}) representing intermarket relationships of conditional volatility are not significant for all three periods except β_{cf} for the second period. These results differ from U.S. findings, which show significant bidirectional intermarket dependence. Furthermore, no systematic differences between the first (bull) and the second (bear) periods are observed for any of the coefficients in the conditional volatility equation except β_{cf} for the second period.

The coefficients that measure the intermarket relationship of return shocks on volatility in the other market are significant in the futures to cash direction, but not in the opposite direction during the first and the second periods. Returns shocks in the futures market exhibit a strong and significant effect on stock volatility. However, returns shocks in the stock market do not show any significant impact on the futures market.

The unidirectional information flow observed in this study is different from the results given in Chan et al. (1991), which show bidirectional information flow between two markets.[21] Furthermore, during the third period, an insignificant α_{cf} implies that the stricter measures appear to reduce the information flow from the futures to the cash market.

SUMMARY AND CONCLUSIONS

This study examines the time series properties of intraday returns for the stock index and the stock index futures in Japan. The sample covers an interesting time period, providing a unique opportunity to examine whether the peculiar Japanese trading system (special price quotation) prevents both the futures and stock prices from experiencing extreme fluctuations. The results show that the price movement limit and the waiting time that limits movements in quotes and execution prices affect futures markets trading.

After the introduction of stricter measures on the OSE in August of 1990, the nontrading probability in the intraday period became much larger. However, the stricter measures did not reduce the variability of prices: the volatilities of both cash and futures prices increase during 1990, especially after the introduction of the stricter measures. Concerning the intraday lead–lag relationship, these stricter measures appear to reduce the speed of information dissemination in the futures markets. In contrast to Lim's finding, the empirical evidence presented in this article indicates that futures returns strongly lead cash returns for all three periods, but third-period futures returns do not lead stock returns as much as the first-period and the second-period futures returns.

No bidirectional information flows such as "a full feedback system" are observed between the two markets in terms of return volatilities, in contrast to U.S. findings. Instead, it is found that futures market shocks to the conditional volatility of the cash market are significant for the period before the stricter measures were introduced. These findings are consistent with the view that market-wide new information disseminates in the futures market first and subsequently in the cash

[21]The impulse response functions implied by the system are examined as in Chan et al. (1991). The results are qualitatively the same as reported in this section.

market. However, since the stricter measures were introduced, this pattern appears to have diminished. This is consistent with the view that the Ministry of Finance and the OSE achieved their objective of reducing the influence of futures market trading on the cash markets, though at the expense of infrequent trading of the futures markets. The cash market shock on the futures markets is not significant at all for all three periods. The intermarket dependence of conditional volatilities is insignificant. Past conditional volatility affects only the current conditional volatility of its own market.

The OSE has introduced tighter restrictions on futures trading four times since August 24, 1990. During this time, the margin has been raised from 9% to 30%. The maximum price range for special price quotations has been reduced from 90 yen to 30 yen at the index level of 20,000. The waiting time for soliciting counter orders was extended from 3 minutes to 5 minutes. These changes may have further affected futures trading on the OSE.[22]

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