Impact of Tick and Contract Size on Intraday Price Discovery Process

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The Nikkei 225 Stock Index is the most quoted index for the Asian equity markets, and its futures product, the Nikkei 225 Futures are globally the most actively traded stock index future representing the Japanese market. In addition, investors' ability to participate in Japanese markets was enhanced by the 2006 introduction of Nikkei 225 mini futures, which are one tenth of the size of the original Nikkei 225 Futures contract. Using minute-by-minute intraday transaction data, this study investigates the contribution that trading in Nikkei 225 Futures and mini futures makes to price discovery for the Nikkei 225 Index. Empirical study reveals that the mini futures market makes the most significant contribution in the price discovery process, followed by the regular futures, while the Nikkei Stock Average has contributed little to price discovery since mini futures were introduced. This implies that the vehicle with the smaller trading unit and minimum price fluctuation is the major contributor to price discovery for the Nikkei 225.

JEL Codes: C22, G13, and G14

1. Introduction

The Nikkei 225 Stock Index is the most quoted index for the Asian equity markets, and its futures product, the Nikkei 225 Futures are globally the most actively traded stock index future representing the Japanese market. On July 18, 2006, the OSE launched the Nikkei 225 mini futures with a minimum trading unit is one-tenth the size of the regular futures and tick size is one-half of the regular futures. These contract specifications were expected to attract small investors to the futures market, improve market liquidity, and contribute to better price discovery.

Using minute-by-minute intraday transaction data, this study investigates the contribution that trading in Nikkei 225 Futures and mini futures makes to price discovery for the Nikkei 225 Index. Its contribution is twofold. This study is the literature's first attempt to estimate the price discovery interactions among the Nikkei 225 Index, Nikkei 225 Futures, and 225 mini futures since the launch of Nikkei 225 mini futures. In addition, the Nikkei 225 regular and mini futures are traded with the same trading platform, transaction cost schedule, and trading specifications except trading unit and minimum price tick); therefore, we are able to isolate the impact of these two differences on the intraday price discovery process.

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This paper is organized as follows. Section 2 reviews the literature. Section 3 describes the market structure of the OSE. Section 4 describes the database used in this study. Section 5 explains the model and Section 6 the empirical results. Section 7 concludes the paper.

2. Literature Review

Several previous studies have examined price discovery between stock index futures and their E-mini contracts. Roope and Zurbruegg (2002) examined the price discovery process of the Taiwan Index Futures listed on the Singapore Exchange (SGX) and the Taiwan Futures Exchange using the models of Hasbrouck (1995) and Gonzalo and Granger (1995). They found that the SGX dominates price discovery for the Taiwan Index Futures.

Hasbrouck (2003) adopted his earlier methodology (Hasbrouck, 1995) to investigate the price discovery process between major stock indexes and their futures products in U.S. markets. He revealed that E-mini futures contribute markedly to price discovery for the S&P 500 and Nasdaq-100, and price discovery is shared between exchange-traded funds (ETF) in the S&P 400 MidCap Index. So and Tse (2004) explored price discovery among Hang Seng Index markets adopting the models of Hasbrouck (1995) and Gonzalo and Granger (1995). Their empirical results suggested that the Hang Seng Index futures market is the main driving force in the price discovery process, followed by the Hang Seng Index, and that the index ETF contributes little to price discovery.

Tse, Bandyopadhyay et al. (2006) investigated the dynamics of price discovery among the Dow Jones Industrial Average (DJIA) and three of its derivative products—regular futures, E-mini futures, and the ETF. They found that the price discovery process for the DJIA is relatively dominated by ETFs traded on the ArcaEx. Kurov (2008) investigated the effect on price discovery for the Nasdaq-100 of reducing the minimum trading tick for regular and E-mini futures. Using the model of Hasbrouck (1995), Kurov found that the reduction in tick size improved price discovery.

Covrig, Ding et al. (2004) focused on the price discovery process pertinent to the Nikkei 225 index. Specifically, they explored the price discovery process occurring among three vehicles: the Nikkei 225 index, the Nikkei 225 futures listed on the OSE, and the SGX. Using the methods of Hasbrouck (1995) and Gonzalo and Granger (1995), they provided evidence that futures markets dominate spot markets in the price discovery process and that the information share attributed to the OSE and the SGX were almost the same even though trading volume for the SGX was significantly lower than that of the OSE.

3. Institutional Background

The Nikkei 225 Stock Index is comprised of 225 leading companies listed on the first section of the TSE. These companies are selected on the basis of liquidity and sector diversity by Nikkei Inc. The index is calculated at one-minute intervals during the trading hours of the TSE (9 to 11 a.m. for the morning session and 12:30 to 3 p.m. for the afternoon session)[i].

Table 1 summarizes contract specifications for Nikkei 225 regular and mini futures, both of which are traded on the OSE, Japan's largest stock index futures market. The OSE operates an electronic order-driven trading system. Regular and mini futures feature almost identical trading specifications, except for contract size and minimum tick size.

Trading hours for the futures are 9 to 11 a.m. (morning session), 12:30 to 3:10 p.m. (afternoon session), and 4:30 to 8:00 p.m. (evening session)[ii]. Each session starts with a call auction followed by continuous trading in which orders are matched on a price-order priority and end with a call auction.

On any trading day, five futures defined by differing expiration dates are traded. The expiration months are the March, June, September, and December nearest to the trading day. On most trading days, the nearby contract is the most actively traded. Daily price limits are approximately 2% above and below the previous day's closing price. Trading is halted for 15 minutes when the price of the contract fluctuates by a predetermined number of points from the previous day's close and deviates from its theoretical value by a predetermined amount denominated in Japanese Yen.

Nikkei 225 mini futures were launched on July 18, 2006. The minimum trading unit for the regular futures contract is ¥1,000 times the Nikkei Stock Average, whereas the unit for the mini futures is half that of regular futures. The minimum price tick of the mini futures contract is ¥5, one-half that of regular futures.

Table 1: Contract Specifications of Nikkei 225 Futures Market

	Nikkei 225 Regular Futures	Nikkei 225 Mini Futures
Underlining Index	Nikkei 225 Index	
Contract size (x the Nikkei 225)	1,000 Yen	100 Yen
Tick size	10 Yen	5 Yen
Contract month	Mar, Jun, Sep, Dec cycle (5 contract months traded at any one time)	
Trading hours (JST)		
Morning session	9:00 a.m. – 11:00 a.m.	
Afternoon session	12:30 p.m. – 3:10 p.m.	
Evening session	4:30 p.m. – 8:00 p.m.	
Daily price limit	Daily price limits are approximately 2% above and below the closing price of the previous day.	
Circuit breaker	Trading will be halted for 15 minutes when the price of the contract fluctuates by a predetermined number of points from the previous day's close and deviates from the theoretical value by a predetermined amount denominated Japanese yen.	

4. Data

The dataset considered in this paper is constructed from transaction data for Nikkei 225 regular and mini futures traded on the OSE. Transaction data on the OSE are taken from the Historical Tick Data database provided by the OSE. Trading time (time-stamped in one-second resolutions), expiration month, trading price, and volume are recorded for each transaction in the database. Since transaction data are not sampled in equally spaced time intervals and the Nikkei 225 Index is computed at one-minute intervals during trading hours, minute-by-minute data are constructed. This conversion allows the application of standard time series analysis.

We excluded data recorded when the Nikkei 225 Index was not computed. That is, sample trading hours are 9:00 a.m. to 11:00 a.m. and 12:30 p.m. to 3:00 p.m. We also focus only on the most actively traded futures in each trading day because of liquidity. The period of the data sample spanned the 40 trading days before and 100 trading days after the Nikkei 225 mini was launched. To mitigate short-term effects associated with the launch, the 60 trading days immediately following the launch day were deleted from the sample. After these application of these criteria, each sub-period consisted of 40 trading days from May 22, 2006, to July 14, 2006, (hereafter the pre-period), and from October 13, 2006, to December 11, 2006, (hereafter the post-period).

5. Model

Estimating the information shares of the regular and mini futures of the Nikkei 225, I adopted the model proposed by Hasbrouck (1995). Following is a brief review of Hasbrouck's model. See Hasbrouck (1995) and Hasbrouck (2003) for detailed estimation procedures.

In Hasbrouck's model, information shares are calculated by estimating the vector error collection model:

$$\Delta p_t = A_1 \Delta p_{t-1} + A_2 \Delta p_{t-2} + \cdots + A_k \Delta p_{t-k} + \gamma (z_{t-1} - \mu_z) + u_t \quad , \qquad (1)$$

where $p_t = \{p_{i,t}\}$ is an $(n \times 1)$ price vector, which refers to the same financial asset. The variable n represents the number of prices, and $z_t - \mu_t$ is the error correction term, where $z_t = (p_{1t} - p_{2t}, p_{1t} - p_{3t}, ..., p_{1t} - p_{nt})'$ and μ_z is the average vector of z_t. $A_1, ..., A_k, \gamma$ are the coefficient matrices, and u_t is the error term vector assumed to be normally distributed with zero mean and constant covariance matrix Ω.

The vector moving average representation of the model is

$$\Delta p_t = B_0 u_t + B_1 u_{t-1} + B u_{t-2} + \cdots \quad , \qquad (2)$$

where B_0 are the identity matrices. From equation (2), cumulative impulse response functions are derived as follows:

$$\psi_k = \sum_{i=0}^{k} B_k \quad . \qquad (3)$$

The first column of ψ_k indicates prices subsequent to a shock in the first asset price. The cumulative price changes in the long run are

$$\Psi = \lim_{k\to\infty} \psi_k \quad (4)$$

Let ψ be any row of Ψ. Since prices are co-integrated, the rows of Ψ are identical. If Ω is diagonal, information share of the j th financial asset, S_j, is defined as

$$S_j = \frac{\psi_j^2 \Omega_{jj}}{\psi \Omega \psi'} \quad (5)$$

where ψ_j is the j th element of ψ and Ω_{jj} is (j, j) th element of Ω.

If Ω is not diagonal—i.e., the residuals of equation (1) are correlated contemporaneously—the information share is not exactly identified. Hasbrouck (1995) proposed the formula for calculating information share in the case that Ω is not diagonal, as follows:

$$S_j = \frac{\left([\psi F]_j\right)^2}{\psi \Omega \psi'}, \quad (6)$$

where F represents the Cholesky factorizations of Ω. Since F depends on the ordering of variables in the factorization, S_j is also not uniquely defined, and we determine lower and upper bounds of S_j by considering the Cholesky factorizations of all permutations of the disturbances.

Following Hasbrouck (1995), the lower and upper bounds of the information share are estimated for each trading day. Since there is a lunch break each trading day for the Nikkei 225 futures, the model is estimated separately with data from the morning and afternoon sessions, and the daily information share is calculated as the weighted average of information shares for the morning and afternoon sessions. The weights are the duration of trading hours in the sessions.

6. Empirical Results

6.1 Descriptive Statistics

Table 2 shows descriptive statistics of the number of trades and trading volume during the pre-period and post-period. The daily number of trades for regular futures in post-period is less than that of the pre-period. The standard t-test rejects the null hypothesis of the equal average between two subsamples. The Wilcoxon sign rank test also rejects that the null of the median of two subsamples are equal. The paired t-test shows that the average number of mini futures is larger than that of regular futures during the post-period at the 1% significance level.

The t-test and Wilcoxson sign rank test indicate at the 1% significance level that daily trading volumes of the regular futures decreased after the launch of the mini futures.

Table 2: Descriptive Statistics of Daily Number of Trades and Trading Volumes

	number of trades			trading volumes		
	Regular		Mini	Regular		Mini
	pre-period	post-period	post-period	pre-period	post-period	post-period
Mean	9744.2	6535.9	10469.7	101432.5	79118.3	72066.8
s.d.	2805.2	1061.4	1128.8	30978.4	14340.9	8783.3
minimum	5511	4417	7796	56550	51728	51259
1st quantile	7505.5	5813.0	9722.3	77077.5	68314.8	66891.5
median	9043.5	6479.5	10516.5	100402.0	81081.0	72769.0
3rd quantile	11233.3	7238.0	11065.0	115441.0	86909.3	77488.0
maximum	19681	9139	12774	198527	115748	92700

Note: pre-period and post-period consist of 40 trading days from May 22, 2006, to July 14, 2006, and from October 13, 2006, to December 11, 2006. The launch date of the Nikkei 225 Mini futures on the OSE was July 18, 2006.

Table 3 shows descriptive statistics of transaction volume per transaction during the continuous auction during trading hours. The statistics indicate that distribution of contracts per trade is heavily skewed. Contracts per trade increased after the launch of the mini futures. The Wilcoxon sign rank test rejects the null of the same median of contracts per trade before the pre-period and post-period.

Table 3: Descriptive Statistics of Contracts per Trade

	volume per transaction		
	regular		mini
	pre-period	post-period	post-period
Mean	9.60	10.76	6.46
s.d.	26.81	32.89	15.57
Minimum	1	1	1
1st quantile	1	1	1
Median	1	2	2
3rd quantile	5	5	5
maximum	654	800	500

Note: pre-period and post-period consist of 40 trading days from May 22, 2006, to July 14, 2006, and from October 13, 2006, to December 11, 2006. The launch date of the Nikkei 225 Mini futures on the OSE was July 18, 2006.

6.2 Impulse Response

Figure 1 shows the cumulative impulse response function estimated from equation (1) for the pre-period sample. Since impulse response and the information share were calculated every session in the sample periods, the figures illustrate the average response in each sub-sample. Panel A of Figure 1 depicts the cumulative impact of a price shock (1 Yen) in the Nikkei 225 Index on itself and on the Nikkei 225 regular futures before the mini futures were launched. During the pre-period before introduction of the mini futures, the impact of a price shock remained about 10% over a 31-minute time horizon and converged in about 15 minutes, while Panel B of Figure 1 indicates that the price shock to the Nikkei 225 regular futures remained about 80% over that same interval. Figure 2 depicts the cumulative impulse response function estimated with the post-period. The duration of price adjustment for arbitrage trading is almost same as that of the pre-period. Also, there is no significant change in the price impact on the Nikkei Stock Average. The impact of Nikkei 225 regular futures is, however, considerably decreased following the launch of the mini futures. That is, the impact that remains in the long-run is decreased from 80% to 12%. On the other hand, the Nikkei 225 mini futures account for 70% of the price impact.

Figure 1: Culmutive Impulse Response Functions(Pre-period)

Panel A: Shock to Nikkei 225 Regular Futures (pre-period)

Panel B: Shock to Nikkei 225 Mini Futures (pre-period)

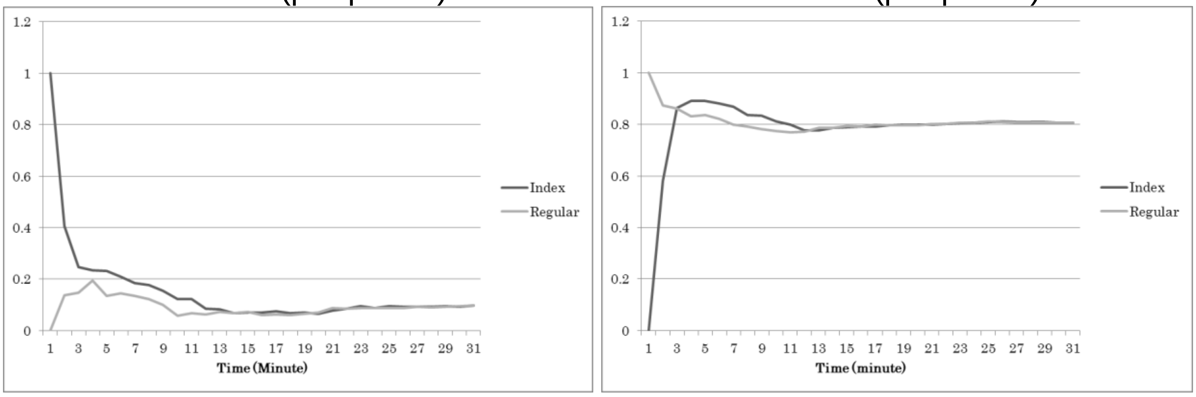
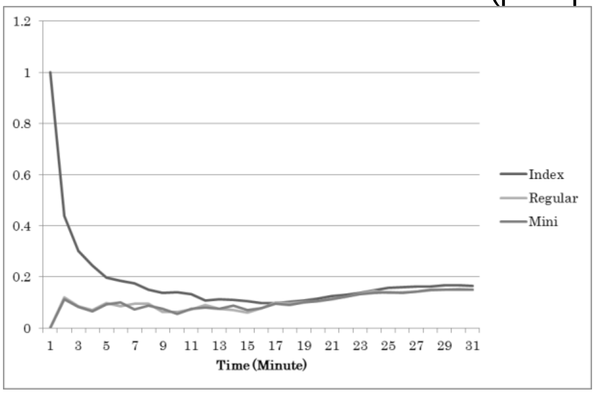
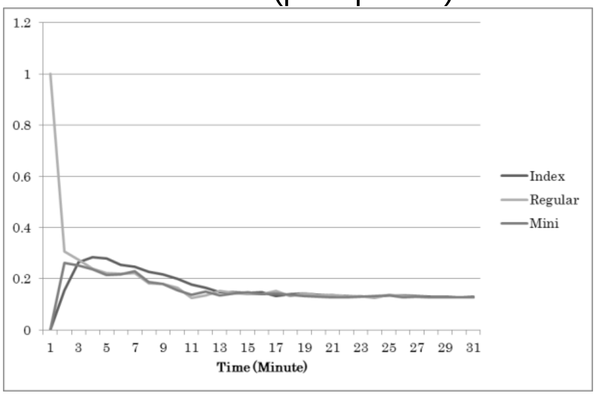


Figure 2: Culmutive Impulse Response Functions (Post-period)

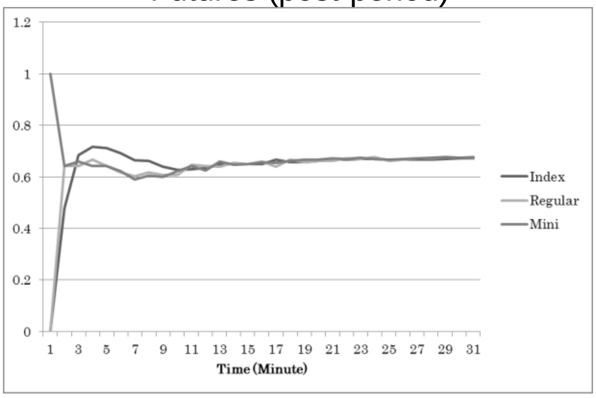
Panel A: Shock to the Nikkei 225 Index (post-period)



Panel B:Shock to Nikkei 225 Regular Futures (post-period)



Panel C:Shock to Nikkei 225 Mini Futures (post-period)



6.3 Information Share

Table 4 shows the average daily information share of Nikkei 225 regular and mini futures. During the pre-period before the Nikkei 225 mini futures, the information share of the regular futures was dominated by its underlying index. That is, the average maximum information share for the regular futures was 92%, while the share of the Nikkei 225 Index was 20%. The information share of the regular Nikkei 225 futures decreased about 38% after Nikkei 225 mini futures were introduced, while the information share of the Nikkei 225 Index was almost the same as its share in the pre-period. The newly launched Nikkei 225 mini contributed about 20% to price discovery. The fact that the information shares of regular Nikkei 225 futures on the OSE were not significantly reduced implies that other factors may contribute to the price discovery process.

Table 4: Information Shares of the Nikkei 225 Index and Futures

	pre-period		post-period	
	maximum	minimum	maximum	minimum
Nikkei 225 Index	0.200	0.076	0.197	0.125
Nikkei 225 Regular Futures	0.924	0.800	0.580	0.087
Nikkei 225 Mini Futures			0.733	0.291

Note: pre-period and post-period consist of 40 trading days from May 22, 2006, to July 14, 2006, and from October 13, 2006, to December 11, 2006. The launch date of the Nikkei 225 Mini futures on the OSE was July 18, 2006.

7. Summary and Conclusions

Using minute-by-minute intraday transaction data, this study investigates the contribution that trading in Nikkei 225 Futures and mini futures makes to price discovery for the Nikkei 225 Index. Following Hasbrouck (1995), cumulative impulse response functions and information shares of Nikkei Stock Average and its derivative products were estimated. Since the Nikkei 225 regular and mini futures are traded with exactly the same trading platform, transaction cost schedule, and trading specification except for the minimum trading tick size and the contract price, we were able to investigate the impact of these differences on the intraday price discovery process.

The descriptive statistics of the daily number of trades, trading volume, and trading volume per transaction show that the launch of the Nikkei mini futures reduced the trading activity of regular futures, while the mini futures successfully attracted small investors and are traded actively. The estimated results of the cumulative impulse response functions suggest that prior to introduction of the mini futures, the impact of a unit price shock on the Nikkei 225 Index died quickly, while the shock's effect on the price of the regular futures contract remained at 80%. This finding implies that the price impact of Nikkei 225 futures is stronger than the Nikkei 225 Index and that the stock index contributes less to price discovery. This result is consistent with Covrig, Ding et al. (2004)

The unit price shock to the mini futures remained above 60% in the long-run, and dominated the Nikkei 225 Index and the regular futures in the post-period after mini futures were launched. This result implies that mini futures, with their smaller contract price and/or price fluctuation have significant price impact. Consistent with results of the impulse response function, information share of the regular futures was significantly greater than the share of the Nikkei 225 Index in the pre-period. Moreover, the mini futures market was the main driving force in the price discovery process, followed by the regular futures, and the Nikkei 225 Index contributed little to price discovery in the post-period. These empirical results imply that price discovery occurs in the financial vehicle trading in smaller units and minimum price fluctuations.

End Notes

[i] From January 4, 2010, the Nikkei Stock Average is calculated every 15 seconds.
[ii] From July 20, 2010, the OSE extended the closing time for the evening session from 20:00 to 23:30.

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