Time-varying Bid-Ask Components of Nikkei 225 Index Futures on SIMEX

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May 1999

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We thank Roger Huang for his helpful comments by private correspondence.

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ABSTRACTS

This paper investigates the time-varying behavior of the bid-ask spread components of Nikkei 225 index futures contract on the SIMEX. According to Huang and Stoll (1997), intraday transaction data are analyzed using simple trade indicator models during 1993-1996. The empirical results support the presence of a large inventory holding cost (63.4%) and a smaller adverse information cost (3.7%). Time-varying analyses show L-shaped pattern of the adverse information costs and reversed U-shaped pattern of the inventory holding costs during a day. Moreover, for the last 15 minutes when only the SIMEX opens (TSE-non-trading period), a large portion of adverse information cost (7.79%) is observed.

1. Introduction

Liquidity is one of the most important characteristics for organized financial market. To maintain liquidity, many organized exchanges use market makers who stand ready to buy or sell whenever the public wish to sell or buy. Bid-ask spread is a major source of revenue for market makers, and is the most important quantity that market makers control in their interactions with other market participants. Consequently, the bid-ask spread has long been of interest to academic researchers as well as traders and regulators, and the biggest area of market microstructure studies. Since Demsetz (1968), many theories of the bid-ask spread have been developed. Market microstructure theory attributes the bid-ask spread to three primary cost components: order processing, inventory holding and adverse information costs. Order processing cost consists of the basic setup and operating costs of trading and bookkeeping. And inventory holding cost is related to the opportunity and carrying cost of undesired inventory which is subject to price risk. Meanwhile, adverse information cost arises because some investors are better informed about a security's value than market makers. Since market makers can not distinguish the informed from the uninformed, they are forced to enlarge the spread to protect themselves from the possible losses by the informed traders.

Up to now two classes of statistical models have been developed to decompose the components of bid-ask spread. One is the covariance-spread model. The seminal paper by Roll (1984) makes an inference about the bid-ask spread, which is modeled by the serial covariance properties of observed transaction prices. Other covariance spread models include Choi, Salandro, and Shastri (1988), Stoll (1989), and George, Kaul, and Nimalendran (1991). Another class is the trade indicator model, which is originally invented by Glosten and Harris (1988). This category includes Madhavan, Richardson, and Roomans (1997). Recently Huang and Stoll (1997) develop a model, which generalizes previous bid-ask spread models.

Glosten and Harris (1988) estimate Glosten's (1987) decomposition of the bid-ask spread using transaction data for 250 NYSE stocks and conclude that the permanent adverse information cost is present in the data. Using the NMS securities on the NASDAQ, Stoll (1989) finds that the quoted spread contains a large and statistically significant adverse information and order processing costs, while the inventory holding cost is small. He concludes that 43% of the quoted spread is due to adverse information costs, 10% due to inventory holding costs, and 47% due to order processing costs.

Using daily and weekly data for NYSE, AMEX and NASDAQ stocks, George, Kaul, and

Nimalendran (1991) find that the adverse information cost accounts for a much smaller proportion (8 to 13%) of the quoted spread than the proportion (over 40%) previously reported. And order processing costs are the predominant of the quoted spreads. Lin, Sanger, and Booth (1995) use 150 NYSE common stocks from the 1988 Institute for the Study of Security Markets (ISSM) files. They find adverse information cost declines monotonically during a day for all but the largest 1% of all trades and order processing costs tend to be highest during the middle of a day.

Madhavan, Richardson, and Roomans (1997) use 274 NYSE common stocks from the 1990 ISSM files. They find that the average adverse information cost decreases from 51.07% to 36.01% of the implied spread as time goes, and it declines monotonically during a day until the final period where it increases slightly. Huang and Stoll (1997) use 19 of the 20 stocks in the Major Market Index from the 1992 ISSM files. They find that the adverse information cost is 9.6% of the traded spread, the inventory holding cost 28.7%, and the order processing cost 61.7%. They also find that the adverse information cost varies from 1.44% to 21.99% and the inventory holding cost from 9.19% to 73.71%, depending on the sequence of trade sizes.

The differences of these estimates come from two sources: different specifications for the behavior of the bid-ask spread, and different data. Nevertheless, the overall conclusion is that there exists a sizable amount of adverse information cost for individual stocks, and that it declines as time goes. Unfortunately, all of the above studies have focused on the bid-ask spread behavior of individual stocks. If other financial instrument is selected to be analyzed, different conclusion would be obtained.

Let's think of stock index futures. To our knowledge, nobody has tried to decompose its bid-ask spread. The price of stock index futures does not depend on the idiosyncratic information of individual stocks, but heavily on the economic condition and generic stock market information. That is, the number of traders who have more informed is far less in stock index futures markets than in stock markets. Moreover, the stock index futures contracts are more actively traded than individual stocks in general. Consequently, adverse information cost could not be sizable for stock index futures. And because of its high leverage characteristics, no one wants to hold inventory for a relatively long period. It implies that inventory holding cost could be predominant. However, there has been no such empirical evidence, yet.

In this study, the indicator model of Huang and Stoll (1997) is estimated to analyze and decompose the bid-ask spread of the Nikkei 225 stock index futures traded on Singapore

International Monetary Exchange (SIMEX). The SIMEX still use an open outcry system for auction with competing traders. This paper uses high frequency transaction-level data to study time-varying components of the bid-ask spread of Nikkei 225 futures.

The remaining part of this paper is organized as follows: Section 2 presents an intraday behavior of the Nikkei 225 futures prices. It also contains the description of the data used. Section 3 presents the empirical analysis of bid-ask spread components. In section 4, time-varying behavior of bid-ask spread components is shown. Tokyo Stock Exchange (TSE)-trading and non-trading periods are investigated to study the effect of TSE-non-trading on SIMEX Nikkei 225 futures' behavior in section 5. The final section summarizes the results and concludes the paper.

2. Data and Intraday Behavior of the Nikkei 225 Futures

Why Nikkei 225 futures

Nikkei 225 futures contract was listed on SIMEX on September 3, 1986. After SIMEX, the Osaka Securities Exchange (OSE) and Chicago Mercantile Exchange (CME) also listed it. Table 1 presents the annual trading volume of major equity index futures contracts in recent years. Among three Nikkei 225 futures contracts, CME's trading volume is too small to study. From an economic viewpoint, unnecessary regulations have been imposed on the OSE, not on the SIMEX. It implies that the SIMEX may give reliable data of Nikkei 225 futures. Recently, the SIMEX has released transaction data including bid and ask quotes' information. Hence, this study employs the SIMEX Nikkei 225 futures data to analyze its time-varying behavior of bid-ask spread.[1]

[1] It was very hard to get high frequency transaction-level data for any other equity index futures contracts such as S&P 500 index futures on the CME and FT-SE 100 index futures on London International Financial Futures Exchange (LIFFE), when this study was initiated.

Table 1.
Trading Volume of the Major Equity Index Futures Contracts

(Unit: No. of Contracts)

Contracts	Exchange	1995	1996	1997
Nikkei 225 Index Futures	SIMEX	6,456,984	4,887,912	4,844,495
	OSE	7,220,900	7,043,977	7,484,182
	CME	609,720	502,072	417,541
S&P 500 Index Futures	CME	18,852,149	19,899,999	21,294,584
FT-SE 100 Index Futures	LIFFE	3,373,259	3,627,044	3,698,368

Source: Factbook, Futures Industry Institute, 1997, 1998.

Data Description

Intraday tick data for Nikkei 225 futures contracts are taken from the data file compiled by the SIMEX. From 1993 to 1996, tick data for all trading days except for half trading days are used.[2] The last trading day for Nikkei 225 futures contract is the day before the second Friday of the contract month, and the contract is traded actively until two days before last trading day. For the contract month, the second nearby contract is also traded actively. This structure is used to assemble the data. That is, the nearby contract data are selected as a sample, and for the contract month the second nearby contract data are employed. The first transaction price of each trading session of a day is excluded from the sample if it is not preceded by bid-ask quotes. To ensure the integrity of the data, the analysis is confined to transactions coded as regular trades and quotes that best bid and ask are eligible. Each trade is paired with the last quote posted at most 5 minutes earlier but with in the same trading day and trading session. We impose another filters on the data to eliminate outliers or recording errors.[3]

[2] The SIMEX holds only a morning session for the first and last trading days every year.
[3] All transaction prices and quotes must be positive and divisible by 5 (minimum price fluctuation); and asks must exceed bids; bids can not exceed transaction prices and transaction prices can not exceed asks; and a transaction price more than 7.5% (daily price limit) away from the previous day's closing price is eliminated; a trade with percentage spread (spread divided by mid quote) more than 1% is eliminated.

Intraday Behavior

Table 2 shows the summary statistics of Nikkei 225 futures contract traded on SIMEX. Due to the lack of trading volume data, the number of transactions is used as a proxy for trading volume. At a glance, the third row shows similar numbers of transactions over all years, which means that the trading behavior is stable in a sense. As in Huang and Stoll (1997), there exist also some clusters of trades at the same price on the same side of the market without any change in bid or ask quotes. A sequence of such trades could be collapsed to just one order (bunching). However, for a trade size of stock index futures is relatively much bigger than individual stocks, bunching is not considerable. As expected, relatively small number of transactions is excluded from the sample, which contrasts well with Huang and Stoll (1997). Meanwhile, unlike stock markets, most transactions take place at either best bid or ask price preceding the trade[4]. It might be inferred from the lack of hidden limit orders in stock index futures markets. For the estimation of Huang and Stoll (1997)'s trade indicator model, a transaction at ask or between ask and midpoint is coded as a buyer initiated trade, and a transaction at bid or between bid and midpoint as a seller initiated trade.

To analyze time-varying behavior of the spread, a day is divided into 9 time intervals: 07:55-08:25 (30 min.), 08:25-09:05 (40 min.), 09:05-09:45 (40 min.) and 09:45-10:15 (30 min.) for a morning session, and 11:15-11:45 (30 min.), 11:45-12:25 (40 min.), 12:25-13:05 (40 min.), 13:05-13:45 (40 min.) and 13:45-14:15 (30 min.) for an afternoon session. Previous studies have investigated intraday behavior of spread and volumes. For example, empirically quoted bid-ask spreads and volumes exhibit U-shaped patterns over a day. [See Harris (1986), Jain and Joh (1988), McInish and Wood (1992)]. In contrast, because of information asymmetry and uncertainty over fundamentals, theoretical models [See Easley and O'Hara (1992), Madhavan (1992)] and laboratory experiments [See Bloomfield (1996), Bloomfield and O'Hara (1996)] concludes that bid-ask spreads decline monotonically over a day as market participants learn from the trading process.

[4] However, in case of stock markets, considerable number of transactions are traded at the price inside the bid and ask quotes. In case of stock options market, above the 95% of the transactions are traded at either the bid or ask quotes. [See Choi, Salandro and Shastri (1988)]

Table 2.
Summary Statistics for Nikkei 225 Futures Contract

Year	1993	1994	1995	1996	Total
Number of Trading Days	246	246	249	244	985
Number of Transactions	301,243	314,376	349,978	313,675	1,279,272
Number of Transactions Before bunching[a)]	299,708	312,689	348,554	311,966	1,272,917
Transactions At Ask[b)]	149,549	153,637	170,498	154,020	627,704
Transactions Between ask And Midpoint[b)]	41	5	13	1	60
Transaction Occurred At Midpoint	280	88	70	26	464
Transactions Between bid And Midpoint[c)]	32	5	11	0	48
Transactions At Bid[c)]	149,806	158,954	177,962	157,919	644,641

a) For three-way decomposition, all sequential trades at the same price on the same side of the market without any change in bid or ask quotes are collapsed to just one trade.
b) Coded as buyer initiated trade.
c) Coded as seller initiated trade.

Table 3 provides descriptive statistics for the Nikkei 225 futures, for example, trading frequencies, quoted mean bid-ask spreads, mean returns and volatilities in nine intraday time intervals from 1993 to 1996. Ignoring the intermission, it is clear that trading frequency and quoted bid-ask spread exhibit U-shaped patterns reported in the previous empirical studies. While the number of transactions per 10 minutes is around 50 during the first and last time periods, it decreases to around 30 during a midday [See Figure 1]. The mean of quoted spread starts from 6.84 and it decreases to around 6.20, and increases again 6.51 for the last time period [See Figure 2]. Volatilities are estimated by standard deviation of returns and extreme value method.[5] Volatilities show also U-shaped patterns except for the extreme value of the last time interval [See Figure 3].

[5] Parkinson (1980) proposes the extreme value method for estimating volatility. It is calculated as ln(high/low) in the time interval under consideration.

Table 3.
Descriptive Statistics[a)]

Time Interval	No. of Transactions	No. of Transactions/ 10 minutes	Average Quoted Spread (point)	Std. Dev. Spread	Mean Return (%)	Volatility (%)	
						Std. Dev. Return	Extreme Value Method
07:55-08:25	146,141	49.9	6.8412	3.4415	-0.0329	0.4284	0.5767
08:25-09:05	173,961	44.5	6.1356	2.4888	0.0254	0.3496	0.4818
09:05-09:45	168,972	43.2	6.2165	2.6627	0.0091	0.3509	0.4911
09:45-10:15	96,474	32.9	6.2830	2.7658	-0.0207	0.3071	0.3670
11:15-11:45	85,448	29.2	6.3701	2.8247	-0.0517	0.2980	0.3400
11:45-12:25	142,555	36.5	6.0533	2.4867	0.0234	0.2864	0.3796
12:25-13:05	141,551	36.2	6.1896	2.6673	0.0149	0.2714	0.4014
13:05-13:45	170,066	43.5	6.4651	2.8931	-0.0162	0.3808	0.5370
13:45-14:15	147,749	50.4	6.5100	2.9279	0.0247	0.3954	0.4911
1993-1996	1,272,917	40.7	6.3385	2.8131	N.A.	N.A.	N.A.

a) Mean return is calculated for each trading interval, and is not annualized. Extreme value is calculated by ln(highest price/lowest price)*100 for each trading interval.
b) N.A. means not applicable.

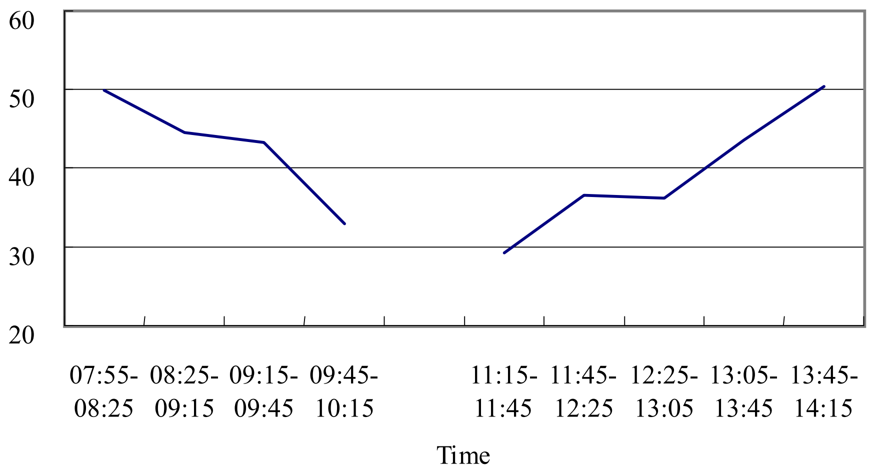

Figure 1.
Number of Transactions Per 10 Minutes (1993-1996)

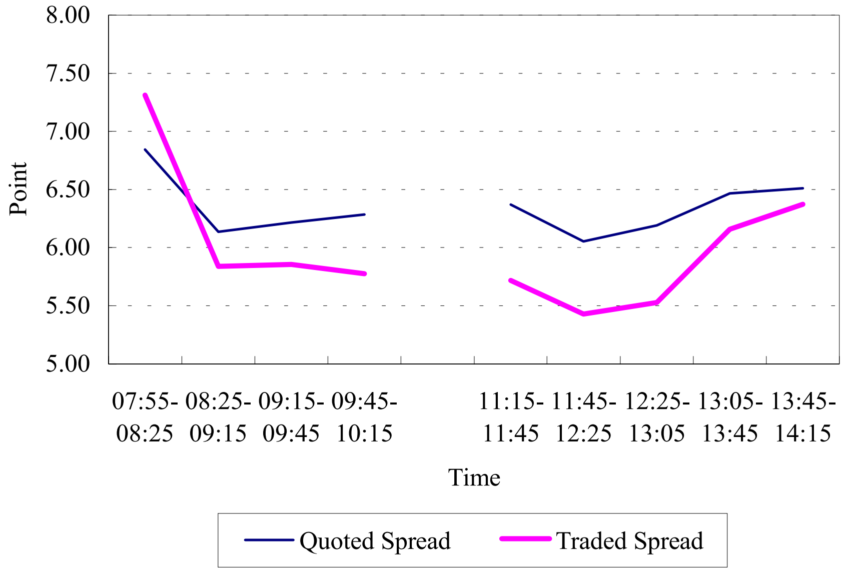

Figure 2.

Quoted and Traded Spread for Nikkei 225 Futures Contracts (1993-1996)

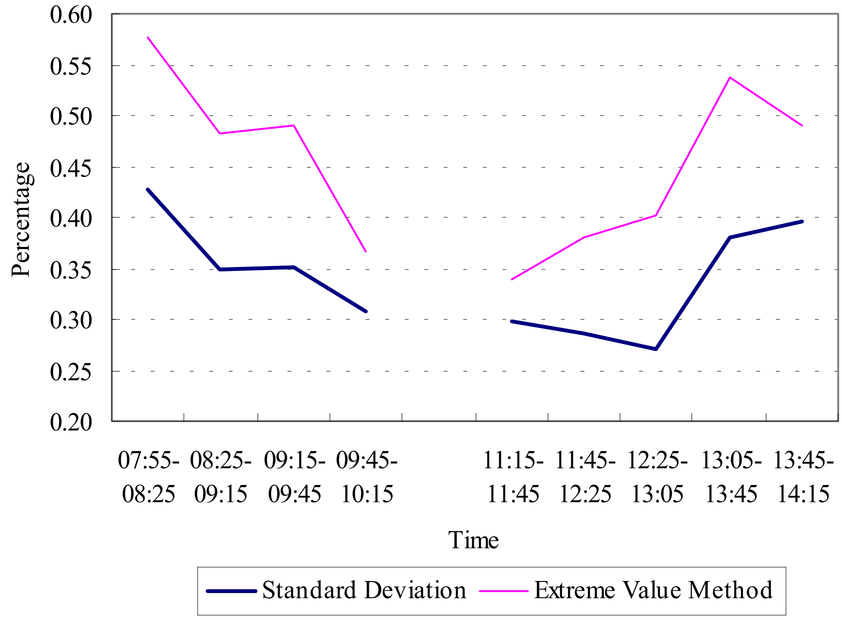

Figure 3.

Intraday Volatility of Nikkei 225 Futures Contract (1993-1996)

3. Analyses of Bid-Ask Spread Components

Two-way Analysis

For the decomposition of bid-ask spread components, various models have been developed. Among them, Huang and Stoll (1997)'s model could be viewed as a general approach within which existing models of spread components are integrated. Here, in this study, their model is employed to decompose and estimate the spread components of Nikkei 225 futures on SIMEX. Along the lines of Huang and Stoll (1997), two-way and three-way decompositions are implemented.

By the two-way analysis, the bid-ask spread is decomposed into an order processing cost and the other. According to the market microstructure theory, the other consists of adverse information and inventory holding costs. For the two-way decomposition, the following basic equation is estimated by generalized method of moments (GMM).

$$\Delta P_t = \frac{S}{2}(Q_t - Q_{t-1}) + \lambda \frac{S}{2} Q_{t-1} + \varepsilon_t \qquad (1)$$

where P_t: transaction price at time *t*

S: constant spread

α: adverse information cost (percentage of half spread)

β: inventory holding cost (percentage of half spread)

$\lambda = \alpha + \beta$

$$Q_t = \begin{cases} 1, & \text{buyer initiated (or transaction above the midpoint)} \\ -1, & \text{seller initiated (or transaction below the midpoint)} \\ 0, & \text{transaction at the midpoint} \end{cases}$$

Q_t is an indicator variable. If a transaction occurs at an ask (bid) quote, it is called 'buyer (seller) initiated.' Estimated results are presented in the Table 4. Traded spread ranges from 5.62 to 6.81, and for the entire period 6.03. They are uniformly less than the average quoted spread for every year.[6] The proportion of the traded spread which is due to the sum of adverse information and inventory holding costs (λ=α+β) ranges from the lowest of 58.3% to the highest of 69.7% for 1994 and 1996, respectively, and 65.7% for the entire

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[6] Estimated traded spread is expected to be less than the average quoted spread because a transaction occurs between bid and ask quotes.

period. As can be easily computed by 1-λ, the order processing costs are 42.7% and 30.3% for 1994 and 1996, respectively, and 34.3% for entire period.

The sum of adverse information and inventory holding costs is significantly larger than those of individual stocks in George, Kaul and Nimalendran (1991), Huang and Stoll (1997), and Madhavan, Richardson and Roomans (1997). From the viewpoint of brokerage fee of future contracts, the lower order processing costs of Nikkei 225 futures is easily expected. Regarding the sum of adverse information and inventory holding costs, the large inventory holding cost seems to operate on it, although it cannot be separately identified in the model. That is, the presence of relatively less informed traders in an active stock index futures reduces the possibility that traders would end up trading with informed traders. And a relatively large size of futures contract and its high leverage characteristics have an effect on the results. It implies that, despite the convenience of offset trading, inventories would be real burden to futures traders.

According to Huang and Stoll (1997), the basic model is extended by introducing volatility size categories. They generalize the above equation by introducing trade size category. Unfortunately, trading volume is not available. This study assumes that the volatility is a proxy for trading volume. Many studies including Jones, Kaul and Lipson (1994) have found positive relationship between volatility and volume (or number of transactions). They suggest that the number of transaction contains more information than the size of trades. As shown from the previous studies, U-shaped patterns of Figures 1 and 3 reveal the positive relationship between the number of transactions and volatility. Here in this study, volatility size is used as a proxy for trade size.

Volatility is calculated by the extreme value method suggested by Parkinson (1980). Traded spread and the sum of adverse information and inventory holding costs are estimated at different spread locations according to the size of volatility, i.e., high, low or normal. At a spread location, extreme values of transaction prices, i.e., the highest and lowest prices, are selected from the preceding 10 successive transactions. The volatility is calculated as the difference between the highest and lowest divided by the lowest. If an extreme value estimate is greater (less) than its average plus (minus) 0.5 times its standard deviation, then it is categorized as high (low) volatility. The interim values will be considered as normal. The allocation process will assign sufficient numbers of observations across three categories.

Using the above volatility categories, the following equation is estimated as in Huang and Stoll (1997) by GMM:

$$\Delta P_t = \frac{S^h}{2} D_t^h + (\lambda^h - 1)\frac{S^h}{2} D_{t-1}^h + \frac{S^n}{2} D_t^n + (\lambda^n - 1)\frac{S^n}{2} D_{t-1}^n + \frac{S^l}{2} D_t^l + (\lambda^l - 1)\frac{S^l}{2} D_{t-1}^l + \varepsilon_t \quad (2)$$

where

avg: average of extreme value estimates of volatility

std: standard deviation of extreme value estimates of volatility

D_t^j (j = h, n, l): indicator variables

$$D_t^h = \begin{cases} Q_t & \text{if extreme value estimate of volatility} > avg + 0.5 \times std \\ 0 & \text{otherwise} \end{cases}$$

$$D_t^n = \begin{cases} Q_t & \text{if avg - } 0.5 \times std \leq \text{extreme value estimate of volatility} \leq avg + 0.5 \times std \\ 0 & \text{otherwise} \end{cases}$$

$$D_t^l = \begin{cases} Q_t & \text{if extreme value estimate of volatility} < avg - 0.5 \times std \\ 0 & \text{otherwise} \end{cases}$$

Table 4.
The Results of Two-way Decomposition[a)]

Year	No. of Obs.	Average Quoted Spread (point)	Traded Spread (S)			Adverse Selection and Inventory Holding (λ)		
			Coeff.	Std. Err.	t-value	Coeff.	Std. Err.	t-value
1993	299,708	7.0141	6.8119*	0.0231	294.72	0.6439*	0.0029	225.82
1994	312,689	6.2428	5.6235*	0.0190	295.88	0.5826*	0.0028	207.69
1995	348,554	6.3115	6.1476*	0.0192	320.89	0.6921*	0.0027	257.43
1996	311,966	5.8157	5.6195*	0.0168	334.89	0.6974*	0.0029	238.57
1993-1996	1,272,917	6.3385	6.0283*	0.0103	583.88	0.6570*	0.0014	457.81

a) Order processing cost components can be calculated by 1-λ.
* Significant at a conventional level.

The above model is exactly identified because the number of parameters and the number of orthogonality conditions are same as 4. Panel A of table 5 presents the GMM estimation results by volatility size categories. The differences in quoted spreads, traded spreads and the sum of adverse information and inventory holding costs among volatility size categories are economically significant in most cases. Interestingly, they are uniformly highest in high volatility period and lowest in low volatility period. It implies that traders extend bid-ask spreads and assume large adverse information and inventory holding costs when the volatility of futures market is high.

Table 5.
Decomposition of Bid-Ask Spread by Volatility Size Categories and Equality Tests[a)b)]

Panel A: Decomposition of Bid-Ask Spread by Volatility Size Categories

Year (Volatility)	No. of Obs.	Average Quoted Spread (point)	Traded Spread (S)			Adverse Selection and Inventory Holding (λ)		
			Coeff.	Std. Err.	t-value	Coeff.	Std. Err	t-value
1993	295,316							
(High)	64,393	8.8956	10.8132*	0.0625	173.03	0.6843*	0.0052	131.49
(Normal)	140,624	6.8158	6.5686*	0.0241	272.80	0.6320*	0.0037	168.71
(Low)	90,855	5.9024	4.2409*	0.0212	199.64	0.5516*	0.0058	95.25
1994	308,297							
(High)	66,333	7.7962	8.7327*	0.0555	157.23	0.6555*	0.0054	121.88
(Normal)	119,523	6.0931	5.6377*	0.0217	260.46	0.5855*	0.0039	148.99
(Low)	122,617	5.4845	3.8300*	0.0165	232.13	0.4780*	0.0045	106.40
1995	344,108							
(High)	77,969	7.4542	9.2105*	0.0526	175.03	0.7091*	0.0050	142.43
(Normal)	149,632	6.1800	6.0640*	0.0213	285.25	0.6926*	0.0037	184.80
(Low)	116,639	5.6329	4.1022*	0.0182	226.08	0.6174*	0.0052	119.43
1996	307,610							
(High)	77,342	6.4521	7.8638*	0.0391	201.39	0.7337*	0.0049	151.00
(Normal)	110,108	5.6961	5.6662*	0.0220	257.73	0.6996*	0.0044	160.44
(Low)	120,212	5.4599	4.0157*	0.0174	230.98	0.6112*	0.0054	114.21
1993-1996	1,255,331							
(High)	283,356	7.6884	9.1498*	0.0274	334.06	0.6958*	0.0026	269.94
(Normal)	518,007	6.1932	5.9900*	0.0117	536.44	0.6590*	0.0020	329.54
(Low)	454,884	5.5932	4.0272*	0.0090	448.17	0.5567*	0.0026	215.43

Panel B: Test Results of Equality

Year	H_0: $S^h = S^n = S^l$		H_0: $S^h = S^n = S^l$ and $\lambda^h = \lambda^n = \lambda^l$	
	$\chi^2(2)$	*p*-value	$\chi^2(4)$	*p*-value
1993	7,766	0.0000	7,851	0.0000
1994	7,027	0.0000	7,066	0.0000
1995	7,668	0.0000	7,763	0.0000
1996	6,872	0.0000	7,120	0.0000
1993-1996	26,675	0.0000	26,906	0.0000

a) Volatility is calculated by the extreme value method, which use the highest and the lowest prices of preceding 10 successive transactions. If the volatility is greater than sum of the mean of extreme values and 0.5 times standard deviation of the extreme values, then that transaction is categorized as high volatility. Normal and low volatility is categorized by the same manners.

b) Order processing cost components can be calculated by 1-λ.

* Significant at a conventional level.

Theoretically, traded spreads are less than or equal to quoted spreads. For the high volatility periods, however, they are estimated larger than the quoted spreads when the volatility of futures market is high. From the theoretical point of view, its economic interpretation is very difficult to accept. This study conjectures that such phenomena are originated from successive changes of bid and ask quotes without any transactions. In a highly volatile market, quotes easily become stale in a very short time. The successive price change could be bigger than bid-ask spread. It seems to make the traded spread larger than average quoted spread in a highly volatile market.

Two constraints can be considered, which impose overidentifying restrictions on equation (2) to examine the variation in the traded spread and λ across volatility size categories. The first constraint is that the traded spreads are same across volatility size categories:

$$H_0: \quad S^h = S^n = S^l \tag{3}$$

The second constraint restricts that both the traded spreads and the sum of adverse information and inventory holding costs are same across volatility size categories:

$$H_0: \quad S^h = S^n = S^l \quad \text{and} \quad \lambda^h = \lambda^n = \lambda^l \tag{4}$$

In GMM estimation, the number of observations times the minimized value of the GMM objective function is approximately distributed as chi-square with the degree of freedom equal to the number of orthogonality conditions minus the number of estimated parameters.[7] In the first case, the number of orthogonality conditions is six and the number of estimated parameters is four. Hence, the degree of freedom of chi-square distribution is two. In the second case, the number of orthogonality conditions is six and the number of estimated parameters is two, which produces the degree of freedom of two.

The results of overidentifying tests are presented in panel B of table 5. The chi-square statistics reject the above two constraints at conventional significance levels. That is, estimated spreads and the sum of adverse information and inventory holding costs are varying according to futures market's volatility. The results imply that it is worthwhile to consider the volatility size categories as spread information.

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[7] For more details see Hansen (1982).

Three-way Analysis

Unlike the above two-way decomposition of spread, three cost components of bid-ask spread can be identified separately in three-way analysis.[8] For the three-way analysis, the following equations are estimated for the bunched data using the restricted GMM method.[9]

$$E[Q_{t-1} \mid Q_{t-2}] = (1-2\pi)Q_{t-2} \tag{5}$$

$$\Delta M_t = (\alpha+\beta)\frac{S_{t-1}}{2}Q_{t-1} - \alpha(1-2\pi)\frac{S_{t-2}}{2}Q_{t-2} + e_t \tag{6}$$

subject to $0 \le \alpha \le 1$, $0 \le \beta \le 1$, and $0 \le \alpha+\beta \le 1$

where

M_t: quoted midpoint calculated from the bid-ask quotes that prevail just before a transaction

S_t: quoted spread at time *t*

π: the probability of a price reversal [i.e., from bid (ask) to ask (bid) prices]

In the case of Huang and Stoll (1997), the number of observations is reduced to approximately 40% of the original data after bunching. However, in the SIMEX data, the number of observations reduced to just 80% of the original data. It means that the number of large trades is fewer in stock index futures trading than in individual stocks.

Table 6 presents the estimated results of extended model based on the bunched data. All the estimates of reversal probabilities are greater than 0.5. However, they are considerably less than those of individual stocks in Huang and Stoll (1997).[10] Important implications can be drawn from these findings. As found in Huang and Stoll (1997), the probability of price reversal is clearly larger for a sequence of two small trades than for a sequence of two large trades. For stock index futures, the trade size is relatively bigger than those of individual stocks. It can be concluded that such characteristics of stock index futures make the probability of price reversal relatively smaller.

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[8] As mentioned before, three cost components are adverse information costs, inventory holding costs, and order processing costs.

[9] For the definition of bunched data, see section 2.

[10] The probability of price reversal ranges from 0.58 to 0.65 in this study, and from 0.72 to 0.97 in Huang and Stoll (1997).

On one hand, the estimates of adverse information cost are ranging from the lowest of 0% for 1994 to the highest of 5.4% for 1995.[11] For the entire period, it is 3.7%, which is strikingly, less than that in Huang and Stoll (1997), i.e., 9.6%. As conjectured from the viewpoint of information asymmetry, the adverse information cost is smaller for stock index futures than for individual stocks. In other words, the absence of asymmetric information for overall stock market lowers the adverse information cost of stock index futures. On the other hand, the estimate of inventory holding cost is 63.39% for the entire period. Across years, they are similar in magnitude. It is also interesting to note large inventory holding costs in the Nikkei 225 futures contracts.[12] It implies that traders are more reluctant to hold inventory in index futures markets than in stock markets, because holding inventory impose relatively higher risk on them. In the same context, the order processing cost is 32.9%, which is relatively smaller.

Table 6.
The Results of Three-way Decomposition[a)]

Year	No. of Obs.	α		β		π	
		Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
1993	240,409	0.0522*	0.0198	0.5846*	0.0206	0.5849*	0.0012
1994	229,724	0.0000†	-	0.6681*	0.0040	0.6292*	0.0012
1995	280,981	0.0541*	0.0204	0.6333*	0.0224	0.6024*	0.0010
1996	263,821	0.0531*	0.0099	0.6482*	0.0105	0.6499*	0.0010
1993-1996	1,014,935	0.0370*	0.0079	0.6339*	0.0086	0.6166*	0.0006

a) Order processing cost components can be calculated by $1-\alpha-\beta$.
* Significant at a conventional level.
† A case which violates non-negativity restriction.

4. Time-varying Behavior of Bid-Ask Spread Components

Time-varying behavior of spread components is also an interesting topic for futures as well as for individual stocks. Intraday tick data of individual stocks have been analyzed by a few studies.[13] Due to the lack of futures tick data, however, nobody has tried to investigate time-varying behavior of futures bid-ask components. Here in this study, time variation of spread components is analyzed. Trading hours of the SIMEX are 7:55-10:15

[11] Especially, the estimate of adverse information cost for 1994 violates the nonnegativity restriction, which lowers its size for the whole sample period.
[12] In Huang and Stoll (1997), inventory holding cost is just 28.65% across all individual stocks.

(140 minutes for a morning session) and 11:15-14:15 (180 minutes for an afternoon session) in Singapore time. A trading day (320 minutes) is divided into nine time intervals as described before. There is sufficient number of observations for each time interval.

Table 7 presents the time-varying behavior of spread components based on two-way analysis. Roughly speaking, the traded spread shows U-shaped pattern during a day as can be seen in figure 2. It is estimated 7.31 for the first 30 minutes, and decreases to around 5.80 for interim time periods, and increases again to 6.37 for the last 30 minutes. The sum of adverse information and inventory holding costs shows reversed U-shaped pattern as can be seen in figure 4. It is estimated 63% for the first 30 minutes, and increases to around 67%, and decreases again to 61% for the last 30 minutes. Meanwhile, order processing cost does not show any specific pattern. Three-way decomposition is needed for more concrete inference.

Table 7.
Time-varying Traded Spread and Its Components: Two-way Decomposition (1993-1996)[a)]

Time Interval	No. of Obs.	Quoted Mean Spread (point)	Traded Spread (S)			Adverse Selection and Inventory Holding (λ)		
			Coeff.	Std. Err.	t-value	Coeff.	Std. Err.	t-value
07:55-08:25	146,141	6.8412	7.3130*	0.0353	207.36	0.6259*	0.0044	142.19
08:25-09:05	173,961	6.1356	5.8382*	0.0235	248.31	0.6537*	0.0037	175.14
09:05-09:45	168,972	6.2165	5.8563*	0.0247	236.88	0.6836*	0.0039	177.77
09:45-10:15	96,474	6.2830	5.7751*	0.0334	172.71	0.6669*	0.0052	128.89
11:15-11:45	85,448	6.3701	5.7173*	0.0352	162.58	0.6877*	0.0055	125.52
11:45-12:25	142,555	6.0533	5.4292*	0.0268	202.60	0.6486*	0.0042	154.33
12:25-13:05	141,551	6.1896	5.5286*	0.0259	213.36	0.6682*	0.0042	160.81
13:05-13:45	170,066	6.4651	6.1588*	0.0256	240.50	0.6999*	0.0038	186.46
13:45-14:15	147,749	6.5100	6.3715*	0.0287	222.06	0.6095*	0.0043	143.15

a) Order processing cost components can be calculated by 1-λ.
* Significant at a conventional level.

Table 8 presents the time-varying behavior of spread components based on three-way analysis using the bunched data. Estimates of the reversal probabilities are all greater than 0.5, averaging 0.62, which is theoretically consistent with Stoll (1989). The adverse information cost shows approximately L-shaped pattern during a day. Except for the first two time periods, it is estimated as zero. During the mid-day, it even violates nonnegativity restriction. The L-shaped pattern is consistent with previous theoretical and

[13] See Lin, Sanger, and Booth (1995), Madhavan, Richardson, and Roomans (1997)

empirical studies that the traders acquire information from the trading processes, and the learning process is reflected in the adverse information cost as time goes.

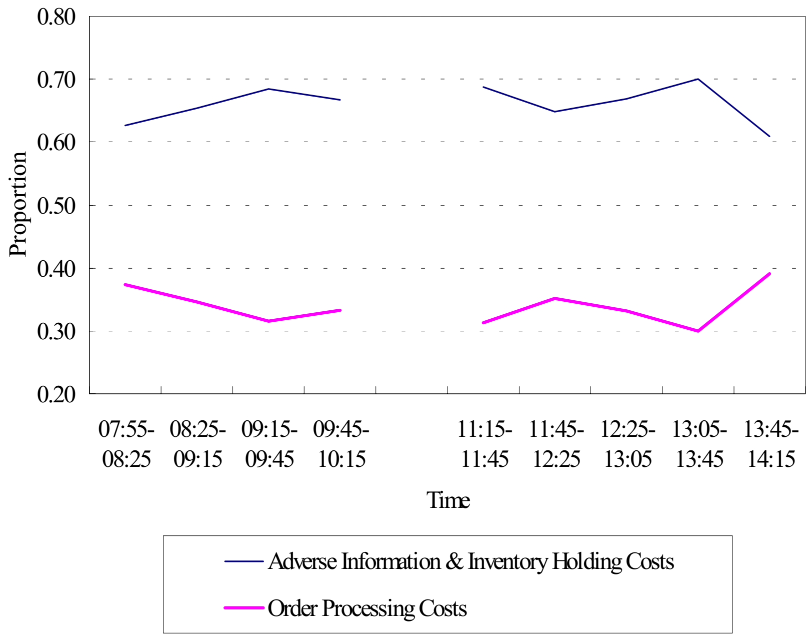

Figure 4.
Two-Way Decomposition of the Spread (1993-1996)

The inventory holding cost shows reversed U-shaped pattern during a day. Very interesting inference could be drawn from the pattern. Due to sufficient liquidity of futures markets, it is easier to close out the current futures positions than those of individual stocks. Nevertheless, as time goes the traders feel uncomfortable for holding inventory because of its high risk. As a result, many of them close out the positions before the market closes. At the start of trading, they hold not so many inventories, which means smaller inventory holding costs. During a mid-day, they endure holding inventories with higher inventory holding costs, because sufficient liquidity makes offset trading easier at any time. As time goes to closing, they decrease their inventories and consequently the inventory holding cost should decrease. The reversed U-shaped pattern of inventory holding costs is consistent with the behavior of futures traders.

Table 8.
Time-varying Components of the Spreads: Three-way Decomposition (1993-1996)[a)b)]

Time interval	No. of Obs.	α		β		π	
		Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
07:55-08:25	123,315	0.1334*	0.0306	0.4169*	0.0337	0.6246*	0.0015
08:25-09:05	139,072	0.0700*	0.0156	0.6070*	0.0167	0.6306*	0.0015
09:05-09:45	135,053	0.0160	0.0182	0.6824*	0.0193	0.6132*	0.0015
09:45-10:15	75,648	0.0000†	-	0.6908*	0.0071	0.6120*	0.0020
11:15-11:45	67,079	0.0000†	-	0.7406*	0.0068	0.6118*	0.0021
11:45-12:25	109,023	0.0000†	-	0.7208*	0.0060	0.6298*	0.0017
12:25-13:05	109,631	0.0000†	-	0.7201*	0.0053	0.6119*	0.0017
13:05-13:45	137,214	0.0178	0.0218	0.6795*	0.0225	0.5933*	0.0015
13:45-14:15	118,900	0.0265	0.0191	0.5821*	0.0200	0.6209*	0.0016

a) The results are based on the bunched data which collapses all sequential trades at the same price with no quote changes to one trade.
b) Order processing cost components can be calculated by 1-α-β.
* Significant at a conventional level.
† A case which violates non-negativity restriction.

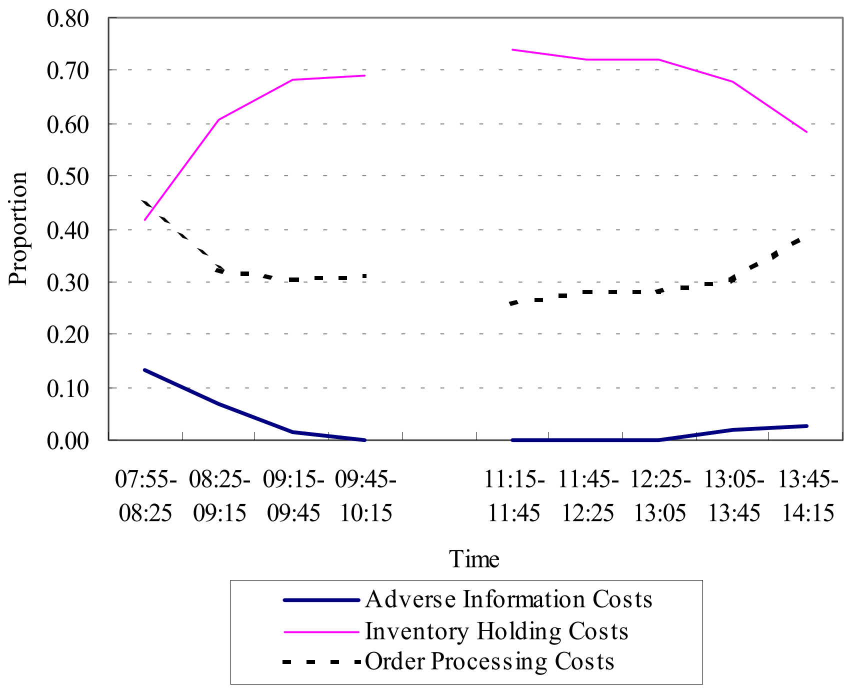

Figure 5.
Three-Way Decomposition of the Spread (1993-1996)

5. More on the Bid-Ask Spread Components

The bid-ask spread components are re-analyzed when only the SIMEX opens, not both the

OSE and TSE (TSE-non-trading period).[14] Table 9 presents trading hours for Nikkei 225 futures contracts and its underlying stocks. Both the TSE and OSE open and close at the same time. However, the SIMEX opens 5 minutes earlier and closes 15 minutes later for a morning session, and 15 minutes earlier and later for an afternoon session. For the first 5 minutes in a morning session and the last 15 minutes in an afternoon session, the traders of Nikkei 225 futures on SIMEX have little information about either the underlying stock market (i.e., TSE) or the other futures market (i.e., OSE). For other TSE-non-trading periods, any peculiar behavior of spread components is not expected because of sufficient business information during a mid-day. As a result, the spread and adverse information cost could be larger for the first 5 minutes in a morning session and for the last 15 minutes in an afternoon session than other time intervals.

At this stage, some peculiar institutional aspects on TSE should be considered. Those are the role of the 'Saitori' member and the 'Itayose' trading method which is a call auction system. On the TSE, all orders placed by member securities firms are transmitted to the Saitori member, who acts as a middleman to match orders. Orders are then gathered by the Saitori and recorded on an order book or on a computer. Because there is no market maker on the TSE, it is possible to have a large bid-ask spread. In such a case, the Saitori issues indicative quotes between the actual bid-ask spread to induce order flows. According to peculiar institutional aspects of the TSE, the overnight information is revealed through Itayose method for the first 5 minutes in a morning session. Hence, the only time interval when the futures traders have little information about underlying stocks would be the last 15 minutes in an afternoon session. Consequently, the adverse information cost could be large for the last 15 minutes in an afternoon session, not for the first 5 minutes in a morning session.

Table 9.
Trading Sessions of Each Exchange (in Singapore Time)

Exchange	Morning Session	Afternoon Session
TSE	08:00 ~ 10:00	11:30 ~ 14:00
OSE	08:00 ~ 10:00	11:30 ~ 14:00
SIMEX[a)]	07:55 ~ 10:15	11:15 ~ 14:15
TSE-non-trading Period	07:55 ~ 08:00 10:00 ~ 10:15	11:15 ~ 11:30 14:00 ~ 14:15

a) Before September 25, 1995, the morning session started at 8:00 a.m.

[14] TSE-non-trading periods are 07:55-08:00, 10:00-10:15, 11:15-11:30, and 14:00-14:15.

Tables 10 present the results of three-way decomposition for TSE-non-trading periods. The price reversal probabilities are larger than 0.5 for all the time periods. As expected, the adverse information cost is significantly large only for the last 15 minutes of an afternoon session, not for the other TSE-non-trading periods. Especially, the Itayose, i.e., a call auction method, has an effect on reducing adverse information during the first 5 minutes' period. Meanwhile the inventory holding cost is smaller for the first 5 and last 15 minutes' periods than for the other periods.

Table 10.
TSE-trading and TSE-non-trading Period Analysis: Three-way Decomposition (1993-1996)[a)]

Time Interval	No. of Obs.	α		β		π	
		Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
07:55-08:00	9,103	0.0004	0.1014	0.4446*	0.1016	0.6044*	0.0055
10:00-10:15	22,107	0.0210	0.0362	0.6577*	0.0396	0.6426*	0.0036
11:15-11:30	20,412	0.0000†	-	0.7797*	0.0130	0.5919*	0.0039
14:00-14:15	53,945	0.0779*	0.0180	0.4675*	0.0199	0.6718*	0.0023

a) Order processing cost components can be calculated by 1-α-β.
* Significant at a conventional level.
† A case which violates non-negativity restriction.

6. Concluding Remarks

This study decomposes the components of the bid-ask spread of the Nikkei 225 futures contracts on SIMEX using Huang and Stoll (1997)'s trade indicator model. High frequency transaction level data from 1993 to 1996 are used. In the two-way decomposition, the sum of adverse information and inventory holding costs shows large proportion (65.7%) of the traded spread. With three-way decomposition, the empirical results show that the inventory holding cost is 63.4% of the traded spread, and the adverse information cost is relatively small (3.7%), and the remaining 32.9% is the order processing cost.

The extended model by volatility size categories is estimated to investigate the effect of volatility on the bid-ask spread components. The two-way decomposition gives a meaningful finding: both the traded spreads and the sum of adverse information and inventory holding costs are highest when the trades belong to high volatility and lowest in the period of low volatility. The estimation results are consistent for all the periods.

Time-varying behavior of spread components produces many interesting findings. In the two-way decomposition, the traded spread shows U-shaped pattern during a day as expected. For the sum of adverse information and inventory holding costs, reversed U-shaped pattern is observed. The three-way decomposition reveals L-shaped pattern of adverse information cost during a day. This coincides with previous theoretical and empirical studies that the traders acquire information from trading process. The reversed U-shaped pattern of inventory holding costs during a day is also interesting.

Furthermore, the bid-ask spread components are re-analyzed when only the SIMEX opens, i.e., TSE-non-trading periods. As expected, the adverse information cost is significantly large only for the last 15 minutes of an afternoon session, not for the other TSE-non-trading periods. Especially, the Itayose, i.e., a call auction method, has an effect on reducing adverse information during the first 5 minutes' period.

This study is just the first trial for investigating the bid-ask spread components of Nikkei 225 futures contracts. The findings are interpreted from an economic point of view. Other futures contracts could be studied for further evidence.

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