行政院國家科學委員會補助專題研究計畫成果報告

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執行期間： 　89 **年** 8 **月** 1 **日至** 90 **年** 7 **月** 31 **日**

計畫主持人：顏錫銘

共同主持人：闕河士

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行政院國家科學委員會專題研究計畫成果報告

期貨市場買賣價差成份之日內型態分析

An intraday analysis of the bid-ask spread components in futures market

計畫編號：NSC 89-2416-H327-023

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主持人：顏錫銘　(國立政治大學財管系)

共同主持人：闕河士　(國立高雄第一科技大學金融營運系)

中文摘要

雖然買賣價的分解在股票市場已有許多實證研究，然而卻未曾有研究對期貨市場進行探討，本研究首次將買賣價差分解模式應用於期貨市場，以新加坡交易所衍生性交易所的日經 225 指數期貨和摩根台股指數期貨為研究對象，研究期間涵蓋 1998 與 1999 二年, 以高頻率的日內逐筆成交價與報價作為實證資料。本研究採用 Lin, Sanger, and Booth (1995)的價差分解模式，估計有效價差的逆選擇成份和委託單處理成本，同時，也對買賣單持續性加以估計。實證結果發現，買賣價差成份大小與股票市場相似。又期貨買賣價差及各成份價差具有顯著的日內型態，期貨有效價差的日內型態呈現開盤高於其它時段，而收盤稍微提高的 U 或反 J 型態。逆選擇成份價差呈現開盤高於其它時段，而後立即下降，並維持穩定的 L 型態。委託單處理成本成份價差呈現開收盤高於其它時段的 U 型態。

關鍵詞：指數期貨；買賣價差；價差分解模式

Abstract

Although the decomposition of bid-ask spreads is studied extensively in the equity market, hardly any study has been done to examine the bid-ask spread components in the futures markets. This study explores empirically the components of bid-ask spreads and their intraday pattern for the Nikkei 255 and the MSCI Taiwan stock index futures contracts traded on the Singapore Exchange Derivatives Trading Limited (SGX-DT). Following Lin, Sanger, and Booth (1995), the spreads are decomposed into order processing cost and adverse selection components. The results show that estimates of daily spread components in the futures market fall within the range of previously reported equity market results. This study also documents significant intraday patterns in effective relative spreads and component spreads in futures markets. For both contracts, the order processing spreads follow a U-shaped pattern, where spreads are relatively high at the open and close in a trading day. We find a L-shaped pattern in adverse selection spreads for the Nikkei 255 stock index futures, with spreads opening high, declining immediately, and then remaining stable during each trading session. The adverse selection spreads are high at the open of a trading day for the MSCI Taiwan index futures. However, a small but significant decrease in adverse selection spreads appears at the end of the trading day. Effective relative spreads are found to be extremely high at the beginning of the trading session, and slightly rising at the end of the trading session, an inverse J-shaped pattern alike, for the Nikkei 255 stock index futures. For the MSCI Taiwan index futures, effective relative spreads are also high at the open but flat in remaining trading hours of the trading day. In general, the findings of this study coincide with the microstructure theory

Keywords: Index futures; Bid-ask spread; Spread decomposition model

INTRODUCTION

In financial markets, dealers or specialists sell financial assets at a price slightly above the perceived equilibrium price and buy financial assets at a price slightly below the perceived equilibrium price. The difference between these two prices is the bid-ask spread. The bid-ask spread represents a major component of a trader's transaction costs. Transaction costs can affect the net gains of investment and market equilibrium price. Thus, many financial scholars and practitioners are always interested in the topic on how to decompose the spreads into various components.

The current literature suggests that the spread can be partitioned into three components: the order processing cost (e.g., Demsetz, 1968; Tinic, 1972; Roll, 1984), the inventory cost, (e.g., Garman, 1976; Stoll, 1978; Amihud and Mendelson, 1980; Ho and Stoll, 1983), and the asymmetric information cost (e.g., Bagehot, 1971; Copeland and Galai, 1983; Glosten and Milgrom, 1985; Easley and O'Hara, 1987). The order processing cost represents the amount required to compensate the dealer for the cost incurred and provide him with a profit. Namely, the order processing cost is the dealer's gross profits and is determined by his cost base and pricing power. The inventory cost represents the amount required to compensate the dealer for the risks incurred in holding the inventory required to perform his supplier of liquidity function, and is determined by the risk of his inventory and his degree of risk aversion. Finally, the asymmetric information cost represents the amount required to protect the dealer from losses to informed traders, who know more about the true asset price than specialists do.

Alternative methods and empirical studies of estimating the composition of bid-ask spreads are proposed. The results display some variation in their estimates of bid-ask spread components because of using different estimation techniques, sample periods, and sample stocks. Although the decomposition of bid-ask spreads is studied extensively in the equity market, hardly any study has been done to investigate bid-ask spread components and their intraday pattern in the futures markets. [1] This study investigates the intraday patern of bid-ask spread components in the index futures market. It would be of great interest to extend existing empirical work to the futures markets because of the different market structure between stock markets and futures markets.

Previous studies document that market trading structure has significant impact on the components of bid-ask spread (see Affleck-Graves, Hegde, and Miller 1994; Porter and Weaver, 1996). On the stock exchanges such as NYSE, there is only one marketmaker or dealer (known as the specialist) per stock. The specialist keeps the limit order book. The specialist is allowed to buy and sell stocks because regulation sets forth the specialist's obligation to maintain fair and orderly market. Thus, the specialist's quotes and public limit orders collectively set the bid-ask spread through the auction-based

[1] There are some studies have analyzed bid-ask spreads in the futures market. These studies deal mainly with seeking the determinants of bid-ask spreads and estimating the intraday behavior of the bid-ask spread (e.g., Ding, 1999; Wang, Michalski, Jordon, and Moriarty, 1994; Ma, Peterson, and Sears, 1992; Laux and Senchack, 1992; Tse, 1999).

market. In the OTC market such as NASDAQ, there may be more one dealer for a stock. These competitive dealers' quotes set the bid-ask spread. Although competition from more dealers forces bid-ask spreads to more competitive levels, it doesn't mean that the specialist has larger pricing power than those multi-dealers have. Researchers have indicate that the competitive degree between the specialist and public orders in the auction-based exchange trading structure is stronger than the competitive degree among dealers in the fragmented competitive market maker structure. Therefore, previous studies document the order processing cost component is lower on specialist exchange than on multi-dealer market.

In the futures market such as SGX-DT, the price of a futures contract is determined by open outcry of bids and offers from locals and floor brokers in an auction market. Locals (usually called scalpers) are individuals who trade for their own account. They are professional risk takers whose presence in the futures market provide liquidity to the market and makes bid and ask prices closer together. Scalpers appear to be a market marker, but have no market making obligations. Sometimes these floor traders are called "quasi" market makers. (Silber, 1984; Kuserk and Locke, 1993; Locke and Venkatesh, 1997) Scalpers' quotes and public orders from floor brokers determine the bid-ask spread through the auction-based market. Obviously, the auction mechanism in futures market is so different from the fragmented competitive market maker structure in OTC. Although futures markets and specialist exchange are based on the auction process to determine the price, they have different trading mechanism. These structural differences may affect the bid-ask spread by two contradictory ways. First, the competition from many scalpers and public orders in the futures market may be stronger than the competition from only one specialist and public orders in stock exchange. In addition, investors in futures markets are on an average better trained and better informed than stock market investors include more professional and institutional investor. Therefore, quasi market makers in the futures markets may have the less pricing power, and then the lower order processing cost. Second, locals in the future market have no obligation to execute their market-making activity. They don't want to incur loss by reducing bid-ask spreads to facilitate the trading during uncertain market conditions. Thus, the order processing cost may be higher in the futures markets. The two opposite inferences highlight the necessity for empirically decomposing bid-ask spread in the futures markets.

The purpose of this paper is to explore empirically the components of bid-ask spread in the index futures market. In particular we examine intraday changes in the spread components. The sample for this study is based on the Nikkei 255 stock index futures contract and MSCI Taiwan stock index futures contract traded on the Singapore Exchange Derivatives Trading Limited (SGX-DT, formerly known as SIMEX). The sample period is from January 1, 1998 to December 31, 1999. All quotes and trades on the nearest contracts are adopted for empirical analysis in this study. Following Lin, Sanger, and Booth's (1995) technique, the spreads are decomposed into adverse selection and order processing cost components for the Nikkei 255 stock index futures contract and MSCI Taiwan stock index futures contract.

We find significant intraday patterns in effective relative spreads and component spreads for two index futures contracts. Order processing spreads follow a U-shaped pattern in both stock index futures, i.e. unusually high at the beginning and at the end of a trading day. The market closure theory proposed by Brock and Kleidon (1992) argues that the liquidity demand from traders adjusting their portfolios before and after market closures creates the larger pricing power of marketmakers. Therefore, it is reasonable to speculate that the quasi-marketmakers in futures markets can enlarge their own net profits through increasing bid-ask spreads at the opening and at the closing. Adverse selection spreads appear high at the open, then decrease immediately, and remain stable during the trading session.

In the MSCI Taiwan stock index futures, the effective relative spread follows the L-shaped pattern, with spreads opening very high and then remaining stable during the trading day. And the similar pattern also appears for the first trading session and the second trading session in the Nikkei 255 stock index futures. An extremely high relative spread appears at the opening for the first trading session, with a moderately high relative spread at the opening and a slightly rising relative spread at the closing for the second trading session. The extremely high relative spread at the opening of a trading day can attribute to both increasing order processing spread and adverse selection spread. As to stable or slightly rising relative spread at the close of a trading day is the mixture of both increasing order processing spread and stable adverse selection spread.

LITERATURE REVIEW

Previous Studies of Spread Decomposition

According to Huang and Stoll (1997), previous statistical models to estimate the components of the bid-ask spread can be classified into two approaches. One is to estimate the spread components by examination of the relation between the spread components and the serial covariance properties of transaction prices. Roll (1984) showed the bid-ask spread can be estimate from the covariance of transaction price changes. His model assumes the existence of only the order processing cost. Stoll (1989) extends the serial covariance framework by including adverse selection and inventory costs. Thus, the bid-ask spread can be decomposed into three components. George, Kaul and Nimalendran (1991) propose an another extended model. Unlike Stoll, they assume the existence of positively autocorrelated time-varying returns and the negligence of inventory cost. Following the works of Roll (1989) and George, Kaul and Nimalendran (1991), McDonald (1994) provides another extended model to allow for time variation in expected returns and interaction between adverse selection and inventory costs.

In another group of models, the spread components are estmated on the basis of a trade indicator model. Glosten and Harris (1988) are the first to solve the decomposition problem in this frame. They decompose the bid-ask spread into transitory and permanent components. The transitory component represents order processing cost and inventory cost, while the permanent component is the adverse selection cost. Following Huang and Stoll (1994), Lin (1992), and Stoll (1989), Lin, Sanger, and Booth (1995) develop empirical estimates of the components of the bid-ask spread. Under setting the inventory cost to be zero, the spread is decomposed into adverse selection and order processing cost components. In addition, the order persistence, which measures the probability of a buy (sell) order following a buy (sell) order, can be estimate from the model. Madhavan, Richardson, and Room (1996) also provide a trade indicator spread model along the lines of Glosten and Harris (1988). Huang and Stoll (1997) construct another trade indicator model. Their extended model, based on serial correlation in trade flow or on trading pressure in other stocks, can separate the spread into three components. Masson's (1993) decomposition model also falls into this category. He decomposes the spread into the realized component and the permanent component. The realized component represents order processing cost and the permanent component reflects adverse selection cost, while the inventory cost is set to be zero.

A number of empirical studies have examined the composition of bid-ask spreads (e.g., Glosten and Harris, 1988; Stoll, 1989; George, Kaul, and Nimalendran, 1991; Wei, 1992; Masson, 1993; Affleck-Graves, Hedge, and Miller, 1994; Mcdonald, 1994; Lin, Sanger, and Booth, 1995; Porter and Weaver, 1996; Madhavan, Richardson, and Roomans, 1997; Huang and Stoll, 1997; Brockman and Chung, 1999). Table I presents a summary of spread components estimated from previous empirical studies. The results display some variation in their estimates of bid-ask spread components because of using different estimation techniques, sample periods, and sample stocks. Taken together, these studies shows that inventory costs appear to be relatively small.[2] Order processing costs and adverse selection costs seem to be the dealer's main costs of providing immediacy services to traders. Besides, most of the results show that the weight of order processing costs is larger than invntory costs.

Additionally, the trading structure (e.g. auction mechanism and multi-dealer negotiating mechanism) and characteristics of the individual stocks (e.g. trade size) are found to have a significant effect on the bid-ask spread components. Empirical evidence indicates that order processing costs are lower on specialist exchange than on multi-dealer market (see Affleck-Graves, Hedge, and Miller, 1994; Porter and Weaver, 1996). The adverse selection component increases with trade size and the order processing cost generally decreases with increases in trade size (see Lin, Sanger, and Booth, 1995).

Intraday Patterns in Bid-ask Spreads and Spread Components

There are several empirical studies have documented that intraday bid-ask spreads follow a U-shaped pattern (or an inverse J-shaped pattern) in equity markets and futures markets. That is, spreads are

[2] George, Kaul, and Nimalendran (1991), Masson (1993), and Lin, Sanger, and Booth (1995) assume negligible inventory holding costs in their model.

unusually high at the beginning and slightly or moderately high at the end of the trading day. In the equity markets, Brock and Kleidon (1992), McInish and Wood (1992), Lee, Mucklow, and Ready (1993), and Lin, Sanger, and Booth (1995) document that the intraday width of bid-ask spreads for New York Stock Exchange (NYSE) stocks follows a U-shaped pattern. Abhyankar, Ghosh, Levin, and Limmack (1997) also find the same pattern in bid-ask spreads for London stock exchange. Hamao and Hasbrouck (1993) find that the bid-ask spreads tend to be higher at the beginning and the end of trading day for stocks traded on the Toronto Stock Exchange. In the futures markets, Ma, Peterson, and Sears (1992) find that bid-ask spreads are higher at the open and close of a trading session on different futures contracts. Wang, Michalski, Jordan, and Moriarty (1994) also find a U-shaped pattern in bid-ask spreads for S&P 500 index futures. Chueh (2000) documents that the significantly wide bid-ask spreads occur near the market open in two trading sessions, and spreads slightly increase at the close in two trading sessions for Nikkei 225 index futures traded on SGX-DT. Ding (1999) shows that bid-ask spreads follows a U-shaped pattern for the Deutsche mark and Japanese yen futures contracts traded on the International Monetary Market of the Chicago Mercantile Exchange (CME).

Only three studies have focused on the intraday pattern of spread compnents, but they document inconsistent results. In McDonald's (1994) study, order processing cost component falls dramatically subsequent to opening, and then keeps the low level over the trading day. Adverse selection component increases through the trading day. Inventory cost component appears no systematic pattern. Lin, Sanger, and Booth (1995) present the results that the relative spread follows a U-shaped pattern for all trade size. The adverse selection component is highest at the beginning of the day and lowest at the end of the day for all but the largest trade size. Order processing cost component tends to be highest during the middle of the day, while the persistence of order of order arrival is highest at the closing of the day. In the article proposed by Madhavan, Richard, and Rooms (1997), the adverse selection dollar spread drops sharply after the opening and remains stable level until the closing where it increases slightly. The transaction cost dollar spread is lower at the opening and increases steadily over the day. The intraday patterns of adverse selection and transaction cost components are similar to the dollar spread. These dissimilar intraday pattern results indicate that researchers should devote their empirical efforts to this work. We just devote our main effort to examining the intraday pattern of bid-ask spread components in this study.

METHODOLOGY AND DATA

Methodology

Because of the emergence early, covariance spread models proposed by Stoll (1989) and George, Kaul, and Nimalendran (1991) are used by several related empirical studies (e.g. Wei, 1992; Affleck-Graves, Hegde, and Miller; 1994; Porter and Weaver, 1996). However, Harris (1990) and Brooks and Masson (1996) have found that noise in price and quote serial covariance estimates causes estimates of spread components to be biased and unreliable. We employ a trade indicator spread model developed by Lin, Sanger, and Booth (1995) to estimate the components of bid-ask spread in index futures markets.[3] Lin et al. use their method to examine the relationship between trade size and spread components in a specialist auction market (i.e. NYSE). Brockman and Chung (1999) have applied Lin, Sanger, and Booth's technique to decompose the bid-ask spread in an order-driven market (i.e. SEHK).

Under an assumption of zero inventory cost, Lin, Sanger, and Booth's method decomposes the spread into order processing cost and adverse selection components, as well as obtains a measure of order persistence that reflects the tendency of a buy (sell) order following a buy (sell) order. Some empirical studies that use alternative estimation methods provide the evidence of small or negligible inventory cost in equity markets (see Table I). The inventory cost would be less important in futures markets because there is no market-making obligation on quasi-market makers (i.e. scalpers) that usually close out all their positions before trading close in a day.

Spread components using the Lin, Sanger, and Booth's methodology for stock index futures are estimated by using ordinary least squares to estimate the following three equations:[4]

$$Q_{t+1} - Q_t = \lambda Z_t + e_{t+1}$$

(1)

$$Z_{t+1} = \theta Z_t + \eta_{t+1}$$

(2)

$$P_{t+1} - P_t = -\gamma Z_t + u_{t+1}$$

(3)

where Q_t denotes the quote midpoint at time t, i.e. $Q_t = (A_t+B_t)/2$; A_t denotes the ask price at time t; B_t denotes the bid price at time t; $Z_t = P_t - Q_t$ is one-half the signed effective spread at time t (with $Z_t < 0$ for a sell order and $Z_t > 0$ for a buy order); P_t denotes the transaction price at time t; λ is the adverse selection component; θ is the order persistence that reflects the tendency of a buy (sell) order following a buy (sell) order; $\gamma = 1 - \lambda - \theta$ is the order processing cost component; and e_t, η_t, u_t are normally distributed error terms. Furthermore, according to the model developed by Lin, Sanger, and Booth (1995), the probability of order persistence (denoted as δ) can be computed as $\delta = (1+\theta)/2$, where $1 > \delta > 0.5$ and $1 > \theta > 0$. When $\delta = 0.5$ (i.e. $\theta = 0$), buy orders and sell orders arrive randomly. Corresponding to Lin et al., the logarithms of the transaction price (P_t) and the quote midpoint (Q_t) are used in our empirical test. This transformation produces estimates of the cost components of the spread as a percent of the effective spread (named as effective relative spread). The effective relative spread is $2|Z_t| = 2|\log(P_t/Q_t)|$ and the effective dollar spread is $2|P_t - Q_t|$.[5] Thus, the order processing spread can be computed as γ times mean effective spread and the adverse selection spread can be computed as λ times mean effective spread.

Data

The sample for this study is based on the

[3] Lin, Sanger, and Booth (1995) point out that "the method used here could be applied to other financial asset markets, such as options, futures, and over-the-counter markets." (see p. 1181)

[4] See Lin, Sanger, and Booth (1995), pp. 1155-1158.

[5] If the transaction prices are executed on the bid or ask prices, the effective spread is same as the quoted spread. On the other hand, the effective spread is smaller than the quoted spread.

Nikkei 255 stock index futures contract and the MSCI Taiwan stock index futures contract traded on the Singapore Exchange Derivatives Trading Limited (SGX-DT, formerly known as SIMEX). The Nikkei 225 stock index futures contract and the MSCI Taiwan stock index futures contract are the first and the second in trading volume among six index futures contracts traded on the SGX-DT over 1999. The sample period is from January 1, 1998 to December 31, 1999. The transaction data is from the SGX-DT trade tick price database on CD-ROM, which contains commodity, contract type, contract month, trading date, quotation time, price, type of price (bid, ask, traded or settlement) for every quotes and transactions. Trades and quotes taking place during ATS are not included in this study.

For the Nikkei 225 stock index futures, the contract size is ￥500 times the Nikkei 225 stock index futures price. The minimum price fluctuation is 5 points, i.e. the value of a tick equals ￥2,500. The contract months of the Nikkei 225 stock index futures are March, June, September, and December contracts listed on five quarterly-months cycle. For the MSCI Taiwan stock index futures, the contract size is US$100 times the MSCI Taiwan stock index futures price. The minimum price fluctuation is 0.1 points, i.e. the value of a tick equals US$10. The contract months of the MSCI Taiwan stock index futures are the nearest 4 March quarterly (Mar, Jun, Sep & Dec) contract months with 2 nearest serial months. Because the trading volume and frequency of succeeding contract are very little before the proceeding contract matures, so this study adopts all quotes and trades on the nearest contracts only for empirical analysis. In the calendar years of 1988 and 1999, there are eight the nearest contracts for the Nikkei 225 stock index futures contract and twelve the nearest contracts for the MSCI Taiwan stock index futures contract. Excluding incomplete trading days and last trading days, there are 466 trading days for the Nikkei 225 stock index futures contract and 507 trading days for the MSCI Taiwan stock index futures contract.[6]

During the sample period, the trading hours of the Nikkei 225 stock index futures is from 07:55 to 10:15 (called first trading session hereafter) and from 11:15 to 14:25 (called second trading session hereafter). For analysis of spread component intraday patterns, the first trading session is divided into six time intervals and the second trading session is divided into eight time intervals. The opening and the closing time intervals of two trading sessions are 20-minute intervals, whereas the others are 25-miunte intervals. For the MSCI Taiwan stock index futures, the trading period is from 8:15 to 12:15. Each trading day is partitioned into seven 30-minute intervals. To estimate spread components from equation (1) to (3) for intraday intervals, we eliminate the time intervals whose transaction number is below thirty. Finally, there are 3,539 observations (i.e. time intervals) for the MSCI stock index futures contract, and 6,405 observations for the Nikkei 225 stock index futures contract.

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[6] The incomplete trading day is the day whose trading hours is shorter than a normal day. Before April 5, 1998, trading hours of the MSCI Taiwan stock index futures are from 8:45 to 11:15 on Saturday. Thus, six 2.5 hours trading days are excluded from the sample. For the Nikkei 225 stock index futures, three days are excluded from the sample, because of only one trading session.

Table II contains descriptive statistics for our two sample contracts. The average daily dollar spread in the MSCI Taiwan stock index futures contract is significantly smaller than the Nikkei 225 stock index futures contract. The possible explanation is lower price level and smaller tick in the MSCI Taiwan stock index futures contract than the Nikkei 225 index futures contract. As to the effective relative spread, the Nikkei 225 index futures contract is significantly smaller than the MSCI Taiwan index futures contract. It may due to the higher price level, smaller price volatility (in terms of standard deviation of returns), larger trading volume, and more trades in the Nikkei 225 index futures contract than the MSCI Taiwan index futures contract (see the last three rows in Table II). Previous empirical studies have reported that the relative bid-ask spread is positively related to the price volatility (e.g., Stoll, 1978; Copeland and Galai, 1983; Wang, Michalski, Jordon, and Moriarty, 1994; Ding, 1999), negatively related to the transaction number (e.g., Harris, 1991; Ding, 1999), trading volume (e.g., Stoll, 1978; Abhyankar, Ghosh, Levin, and Limmack, 1997), and price level (e.g., Stoll, 1978; Branch and Freed, 1977; Menyah and Paudyal, 1996).

INFERENCES ABOUT INTRADAY PATTERNS OF SPREADS AND COMPONENT SPREADS

Previous studies report that spreads are not randomly distributed, so it is meaningful to observe the intraday patterns of component spreads rather than spread components themselves. The order processing cost represents the amount required to compensate the dealer for the cost incurred and provide him with a profit. The order processing cost is the dealer's gross profits and is determined by his cost base and pricing power. Brock and Kleidon (1992) develop a model of intraday spreads where market makers possess larger pricing power and exercise it to take advantage of the liquidity demand of investors to trade around the open and close of a trading day by increasing bid-ask quotes. Their model is named as market maker power theory (also called as market closure theory). Therefore, it is reasonable to speculate that dealers in futures markets can enlarge their own net profits through increasing bid-ask spread at the open and at close. Thus, we infer that the order processing spreads in futures markets may follow a U-shaped pattern, where spreads are widest immediately after the open and preceding the close of a trading day.

The asymmetric information cost represents the amount required to protect dealers from losses to informed traders, who know more about the true asset price than dealers do. Thus, when dealers face the higher uncertainty regarding the true value of an asset, they make the bid-ask quotes widened, vice versa. It is obvious that information acquired overnight would give informed traders the largest advantage early in the day before the information becomes more widely disseminated, either through trading or news releases. Even in the absence of private information, traders can have greater divergences of opinion at the beginning of the day following the overnight nontrading period. Consequently, the bid-ask spreads from asymmetric information would be largest at the open. Madhavan (1992) has developed a model to describe above phenomenon. His model considers traders with diverse information concerning the value of an asset at the open of a trading. As trading continues, private information is impounded into prices, and dealers narrow their spreads as their informational handicap declines. Thus, we infer that the adverse selection spread in futures markets may follow L-shaped pattern, with spread opening high, then declining and relatively stable throughout a trading day.

The relative spreads consist of order processing spreads and adverse selection spreads. According to above arguments, we have a U-shaped pattern in order processing spreads and a L-shaped pattern in the adverse selection spreads. Thus, we can infer that effective relative spreads in futures markets may follow a U-shaped pattern (or a reverse J-shaped pattern). That is, spreads are unusually high at the beginning and slightly or moderately high at the end of the trading day. In fact, there are many empirical studies document that bid-ask spreads follow a U-shaped pattern in equity markets and futures markets.

EMPIRICAL RESULTS

Spreads Decomposition by Trading Days

Table III reports the decomposition results for two sample contracts. The Order processing cost component, the adverse selection component, and the order persistence are estimated by using equation (1) to (3) for each trading day. The order processing spread is computed as γ times mean effective relative spread and the adverse selection spread is computed as λ times mean effective relative spread. Then the average coefficient (i.e. γ, λ, and θ), t-statistic, R-squared, order processing spread and adverse selection spread are calculated across trading days. In addition, the mean equality tests on the order processing cost component, the adverse selection component, the order persistence, order processing spread, and adverse selection spread for two sample contracts are also reported in Table III.

The average estimates of order processing cost components are 29.69 percent and 39.15 percent for the Nikkei 225 stock index futures contract and the MSCI Taiwan stock index futures contract, respectively. Additionally, 458 of 466 estimates for the Nikkei 225 stock index futures contract and 501 of 507 estimates for the MSCI Taiwan stock index futures contract are significant at the 0.01 level. The average estimates of adverse selection components are 41.17 percent for the Nikkei 225 stock index futures contract and 39.49 percent the MSCI Taiwan stock index futures contract. The t-statistics on estimated coefficient λ indicate that all estimates for the Nikkei 225 stock index futures contract and 502 of 507 estimates for the MSCI Taiwan stock index futures contract are significant at the 0.01 level. These estimates of spreads component in the futures market fall within the range of previously reported equity market results (see Table I).

The order processing cost component in the Nikkei 225 stock index futures contract is significantly smaller than the MSCI Taiwan stock index futures contract, however, the adverse selection component is larger. Because the different size of average effective relative spread for the Nikkei 225 and the MSCI Taiwan stock index futures contracts, it is significant to examine the difference of component spreads, not to examine the difference of the spread components for these two contracts. Table III shows that the average order processing spreads in the Nikkei 225 stock index futures contract are significantly smaller than the MSCI Taiwan stock index futures contract. The possible explanation is that the Nikkei 225 stock index futures contract has larger trade size than the Taiwan MSCI stock index futures contract. From Table II, we can find that average trade size (measured by volume) is 11.853 in the Nikkei 225 stock index futures contract and 4.909 in the MSCI Taiwan stock index futures contract. Because of spreading of fixed order costs over more contracts for larger orders, the average order processing costs per contract should decrease as trade size increases. In equity market, Lin, Sanger, and Booth (1995) have also reported that the order processing spread decreases with increases in trade size for NYSE firms.

The adverse selection spreads, reported in Table III, have the same results, i.e., the average adverse selection spread in the Nikkei 225 stock index futures contract is significantly smaller than the MSCI Taiwan stock index futures contract. This finding indicates that the degree of information uncertainty is higher in the Taiwan stock exchange than the Tokyo stock exchange. Recall from Table II that the variance of return on the MSCI Taiwan stock index futures contract is significantly larger than Nikkei 225 stock index futures contract.

The third part of Table III reports the order persistence results for two futures contracts. The average estimates of order persistence are 29.14 percent and 21.36 percent for the Nikkei 225 stock index futures contract and the MSCI Taiwan stock index futures contract, respectively. Additionally, 462 of 466 estimates for the Nikkei 225 stock index futures contract and 495 of 507 estimates for the MSCI Taiwan stock index futures contract are significant at the 0.01 level. Lin, Sanger, and Booth (1995) show that the probability of order persistence (denoted as δ) can be computed as δ=(1+θ)/2. Based on the mean θ coefficients, we estimate δ to be 64.57% for the Nikkei 225 stock index futures contract and 60.68% for the MSCI Taiwan stock index futures. The mean δ is significantly larger than 0.5 (i.e. θ is significantly larger than 0) for both the Nikkei 225 and the MSCI Taiwan stock index futures contracts, the t-statistics are 85.769 and 60.738 respectively. The evidence shows that the tendency of buy (sell) orders following buy (sell) orders is not randomly. The mean equality test on θ indicates that the average order persistence in the Nikkei 225 stock index futures contract are significantly smaller than the MSCI Taiwan stock index futures contract. This evidence can be explained by higher trading activity in the Nikkei 225 stock index futures contract. Recall to Table II, the Nikkei 225 stock index futures contract has lower relative bid-ask spreads, higher trading volume, and larger trade size, so its persistence of order arrival is smaller. Lin, Sanger, and Booth (1995) and Brockman and Chung (1999) have also found that order persistence displays a positive relation to the firms' trading activity. Moreover, Brockman and Chung argue that "With higher depth and lower relative spreads, high-liquidity firms have a greater capacity to absorb a sequence of buy (sell) orders resulting from the release of favorable (unfavorable) information. The adjustment process is continuous and does not lead to large liquidity-related price changes. Low-liquidity firms, on the other hand, lack the market deapths and spreads to absorb new information without liquidity-related price jumps. Relatively large and discrete price jumps mean buys (sells) are less likely to follow buys (sells) for low-liquidity firm than for high-liquidity firms."

Spreads Decomposition by Time of the Day

Again, we use equation (1) to (3) to estimate order processing cost component (γ), adverse selection component (λ), and order persistence (θ) for each time interval of every trading day. Then, the mean γ , λ , and θ , R-squared, t-statistics for each time interval across trading days are showed in Table IV and Table V and graphed in Figure 1 and Figure 2 for the Nikkei 225 and the MSCI Taiwan stock index futures contracts, respectively. The results of F-statistics for equality tests show that there are significant patterns in order persistence through a trading day for both contracts. For the Nikkei 225 stock index futures contract, the order persistence is relatively lower at the first and the last time intervals of a trading day. However, only the last time interval of a trading day appears the lower order persistence for the MSCI Taiwan stock index futures contract. By contrast with Lin, Sanger, and Booth's (1995) study, they finds that the order persistence is lowest in the first hour of trading and highest in the last hour of trading for NYSE firms.

The results of F-statistics for equality tests in Table IV and V also present that spread components vary during the trading day for both contracts. Because effective relative spreads are not randomly distributed in a trading day (see Table X and XI), it is meaningful to analyze the intraday patterns of component spreads rather than spread components themselves. From Table VI and Figure 3, we can find that the order processing spreads in the Nikkei 225 stock index futures follow a U-shaped pattern, where spreads are widest at the open and close of a trading day. As shown in Table VI, the mean equality ANOVA test indicates that the order processing spreads differ significantly during different time intervals of a trading day. The Scheffe multiple comparisons show that the order processing spreads at the open and close trading hours are significantly larger than the other time intervals. The similar results are found for the MSCI Taiwan stock index futures from Table VIII and Figure 4. These results are consistent with Brock and Kleidon's (1992) market closure theory. The fact is that dealers in futures markets possess larger pricing power over the liquidity demand of investors to trade around the open and close of a trading day. Thus, they can enlarge their own net profits through increasing bid-ask spreads at the open and at close.

The adverse selection spreads display a L-shaped pattern in two trading sessions as shown in Table VII and Figure 3. The Scheffe multiple comparisons show that the adverse selection spreads are widest at the first time interval of both trading sessions for the Nikkei 225 stock index futures contract. Similarly, the adverse selection spreads are high at the open of a trading day for the MSCI Taiwan index futures contract.

However, a small but significant decrease in adverse selection spreads appears at the end of the trading day (see Table IX and Figure 4). These evidences indicate that the disagreement with nontrading-hour information makes the spread widen at the open of a trading session or a trading day. By contrast to previous empirical evidence, Madhavan, Richard, and Rooms (1997) have documented a similar result in equity market, where the adverse selection dollar spread drops sharply after the opening and remains stable level until the closing where it increases slightly.

Finally, we also find that effective relative spreads are extremely high at the beginning and slightly rising at the end of both trading sessions (i.e. an inverse J-shaped pattern alike) for the Nikkei 255 stock index futures in Table X and Figure 3. As to the MSCI Taiwan index futures, Table XI and Figure 4 presents that effective relative spreads are also high at the open but flat in remaining trading hours of the trading day. These findings are similar to previous studies focusing on intraday pattern of spreads in futures markets (e.g. Ma, Peterson, and Sears, 1992; Wang, Michalski, Jordan, and Moriarty, 1994; Ding, 1999; Chueh, 2000).

CONCLUSION

This study explores empirically the components of bid-ask spreads and their intraday pattern for the Nikkei 255 and the MSCI Taiwan stock index futures contracts traded on the SGX-DT. Following Lin, Sanger, and Booth (1995), the spreads are decomposed into order processing cost and adverse selection components. The results show that the average daily order processing cost and adverse selection components are estimated to be approximately 30 percent and 41 percent of the bid-ask spread for the Nikkei 255 index futures and 39 percent and 40 percent of the bid-ask spread for the MSCI Taiwan index futures. These estimates of daily spread components in the futures market fall within the range of previously reported equity market results.

The effective relative spread, order processing spread, and adverse selection spread in the Nikkei 225 index futures contract are all significantly smaller than the MSCI Taiwan index futures contract. This distinction can be explained by price level, price volatility (information uncertainty), trading volume, transaction number, and trade size. We also document that there are significant intraday patterns in total relative spreads and component spreads in futures markets. For both contracts, the order processing spreads follow a U-shaped pattern, where spreads are relative high at the open and close in a trading day. A L-shaped pattern in adverse selection spreads, with spreads opening high, declining immediately, and then remaining stable during each trading session, are found for the Nikkei 255 stock index futures. The adverse selection spreads are high at the open of a trading day for the MSCI Taiwan index futures. However, a small but significant decrease in adverse selection spreads appears at the end of the trading day. Effective relative spreads are found to be extremely high at the beginning of the trading session, and slightly rising at the end of the trading session, an inverse J-shaped pattern alike, for the Nikkei 255 stock index futures. For the MSCI Taiwan index futures, Effective relative spreads are also high at the open but flat in remaining trading hours of the trading day. In general, the findings of this study coincide with the microstructure theory.

BIBLIOGRAPHY

Abhyankar, A., Ghosh, D., Levin, E., and Limmack, R. J. (1997): "Bid-Ask Spreads, Trading Volume And Volatility: Intra-Day Evidence from the London Stock Exchange," *Journal of Business Finance & Accounting*, 24: 343-362.

Affleck-Graves, J., Hedge, S. P., and Miller, R. E. (1994): "Trading Mechanisms and the Components of the Bid-Ask Spread," *Journal of Finance*, 49: 1471-1488.

Amihud, Y., and Mendelson, H. (1980): "Dealership Market: Market Making with Inventory," *Journal of Financial Economics*, 8: 31-35.

Bagehot, W. (1971): "The Only Game in Town," *Financial Analysis Journal*, 27: 12-14.

Branch, B., and Freed, W. (1977): "Bid-Ask Spreads on the AMEX and Big Board," *Journal of Finance*, 32: 159-163.

Brock, W. A., and Kleidon, A. W. (1992): "Periodic Market Closure and Trading Volume: A Model of Intraday Bids and Asks," *Journal of Economic Dynamics and Control*, 16: 451-489.

Brockman, P., and Chung, D. Y. (1999): "Bid-Ask Spread Components in an Order-Driven Environment," *Journal of Financial Research*, 22: 227-246.

Brooks, R., and Masson, J. (1996): "Performance of Stoll's Spread Component Estimator: Evidence from Simulations, Time-Series, and Cross-Sectional Data," *Journal of Financial Research*, 19: 459-476.

Chueh, H. (2000): "Price Clustering in the Nikkei 225 Stock Index Futures Contract on the SIMEX: An Intraday Empirical Analysis," *Review of Pacific Basin Financial Markets and Policies*, 3: 519-533.

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

Demsetz, H. (1968): "The Cost of Transacting," *Quarterly Journal of Economics*, 82: 33-53.

Ding, D. K. (1999): "The Determinants of Bid-Ask Spreads in the Foreign Exchange Futures Market: A Microstructure Analysis," *Journal of Futures Markets*, 19: 307-324.

Easley, D., and O'Hara M. (1987): "Price, Trade Size, and Information in Securities Markets," *Journal of Financial Economics*, 19: 69-90.

Foster, F. D., and Viswanathan, S. (1993): "Variations in Trading Volume, Return Volatility and Trading Costs: Evidence on Recent Price Formation Models," *Journal of Finance*, 48: 187-212.

Garman, M. (1976): "Market Microstructure," *Journal of Financial Economics*, 3: 257-275.

Hamao, Y., and Hasbrouck, J. (1993): "Securities Trading in the Absence of Dealers: Trades and Quotes on the Tokyo Stock Exchange," Graduate School of Business, Columbia University, Working Paper.

Harris, L. (1990): "Statistical Properities of the Roll Serial Covariance Bid-Ask Spread Estimator," Journal of Finance, 45: 579-590.

Harris, L. (1991): "Stock Price Clustering and Discreteness," *Review of Financial Studies*, 4: 389-415.

Ho, T., and Stoll, H. R. (1983): "The Dynamics of Dealer Markets under Competition," *Journal of Finance*, 38: 1053-1074.

Huang, R. D., and Stoll, H. R. (1994): "Market Microstructure and Stock Return Predictions," *Review of Financial Studies*, 7: 179-213.

Huang, R. D., and Stoll, H. R. (1997): "The Components of the Bid-Ask Spread: A General Approach," *Review of Financial Studies*, 10: 995-1034.

George, T. J., Kaul, G. and Nimalendran, M. (1991): "Estimation of the Bid-Ask Spreads and its Components: A New Approach," *Review of Financial Studies*, 4: 623-656.

Glosten, L. R., and Harris, L. (1988): "Estimating the Components of the Bid-Ask Spread," *Journal Financial Economics*, 21: 123-142.

Glosten, L. R., and Milgrom, P. (1985): "Bid, Ask, and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders," *Journal of Financial Economics*, 14: 71-100.

Kuserk, G. J., and Locke, P. R. (1993): "Scalper Behavior in Futures Markets: An Empirical Analysis," *Journal of Futures Markets*, 13: 409-431.

Laux, P., and Senchack, A. (1994): "Estimating the Bid-Ask Spread in Heteroskedastic Market: The Case of Foreign Currency Futures," *Review of Quantitative Finance and Accounting*, 4: 219-237.

Lee, M. C., Mucklow, B., and Ready, M. J. (1993): "Spreads, Depth, and the Impact of Earnings Information: An Intraday Analysis," *Review of Financial Studies*, 6: 345-374.

Lin, J. C. (1992): "Order Persistence, Adverse Selection, and Gross Profits Earned by NYSE Specialists," Louisiana State University, Working Paper.

Lin, J. C., Sanger, G., and Booth, G. G. (1995): "Trade Size and Components of the Bid-Ask Spread," *Review of Financial Studies*, 8: 1153-1183.

Locke, P. R., and Venkatesh, P. C. (1997): "Futures Market Transaction Costs," *Journal of Futures Markets*, 17: 229-245.

Ma, C., Peterson, R., and Sears, S. (1992): "Trading Noise, Adverse Selection, and Intraday Bid-Ask Spreads in Futures Markets," *Journal of Futures Markets*, 12: 519-538.

Madhavan, A. (1992): "Trading Mechanisms in Securities Markets," *Journal of Finance*, 47: 607-642.

Madhavan, A., Richardson, M., and Roomans, M. (1997): "Why Do Security Prices Change? A Transaction-Level Analysis of NYSE Stocks," *Review of Financial Studies*, 10: 1035-1064.

Masson, J. (1993): "Estimating the Realized Bid-Ask Spread Using Quote Revisions," University of Ottawa, Working Paper.

Mcdonald, C. G. (1994): "Decomposition of the Bid-Ask Spread: Theory and Empirical Evidence," Ph.D. Dissertation, University of South Carolina.

Mcinish, T., and Wood, R. (1992): "An Analysis of Intraday Patterns in Bid-Ask Spreads for NYSE Stocks," *Journal of Finance*, 47: 753-764.

Menyah, K., and Paudyal, K. (1996): "The Determinants and Dynamics of Bid-Ask Spreads on the London Stock Exchange," *Journal of Financial Research*, 19: 377-395.

Porter, D., and Weaver, D. (1996): "Estimating Bid-Ask Spread Components: Special versus Multiple Market Maker System," *Review of Quantitative Finance and Accounting*, 6: 167-180.

Roll, R. (1984): "A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market," *Journal of Finance*, 39: 1127-1139.

Silber, W. (1984): "Marketmaking Behavior in an Auction Market: An Analysis of Scalpers on Futures Markets," *Journal of Finance*, 38: 937-953.

Stoll, H. R. (1978): "The Supply of Dealer Services in Securities Markets," *Journal of Finance*, 33: 1133-1151.

Stoll, H. R. (1989): "Inferring the Components of the Bid-Ask Spread: Theory and Empirical Tests," *Journal of Finance*, 44: 115-134.

Tinic, S. M. (1972): "The Economics of Liquidity Services," *Quarterly Journal of Economics*, 66: 79-97.

Tse, Y. (1999): "Market Microstructure of FT-SE 100 Index futures: An Intraday Empirical Analysis," *Journal of Futures Markets*, 19: 31-58.

Wang, G., Michalski, R., Jordan, J., and Moriarty, E. (1994): "An Intraday Analysis of Bid-Ask Spreads and Price Volatility in the S&P 500 Index Futures Market," *Journal of Financial Markets*, 12: 621-634.

Wei, P. (1992): "Intraday Variations in Trading Activity, Price Variability and the Bid-Ask Spread," *Journal of Financial Research*, 15: 265-276.

Wood, R. A., Mcinish, T. H., and Ord, J. K. (1985): "An Investigation of Transactions Data for NYSE Stocks," *Journal of Finance*, 40: 723-739.

Table I

Previous Empirical Estimates of the Bid-ask Spread Components

Study	Method	Sample	Spread Components			
			Adverse selection	Order processing cost	Inventory cost	Order persistence
Glosten and Harris (1988)	GH	NYSE	20%	80%		
Stoll (1989)	Stoll	NASDAQ	43%	47%	10%	
George, Kaul, and Nimalendran (1991)	GKN	NASDAQ-daily	4%	96%	0%	
		NASDAQ-weekly	30%	70%	0%	
Wei (1992)	Stoll	NYSE/AMEX	80%	20%	0%	
	GH	NYSE/AMEX	20%	80%		
Masson (1993)	Masson	NASDAQ	12%	88%	0%	
		NYSE	46%	54%	0%	
Affleck-Graves, Hegde, and Miller (1994)	Stoll	NASDAQ	35%	41%	24%	
		NYSE/AMEX	59%	12%	29%	
	GKN	NASDAQ	7%	93%	0%	
		NYSE/AMEX	26%	74%	0%	
McDonald (1994)	McDonald	NASDAQ	11%	88%	1%	
Lin, Sanger, and Booth (1995)	LSB	NYSE	45%	28%	0%	27%
Porter and Weaver (1996)	GKN	NASDAQ	24%	76%	0%	
		NYSE	55%	45%	0%	
		AMEX	46%	54%	0%	
Madhavan, Richard, and Rooms (1997)	MRR	NYSE	43%	57%		
Huang and Stoll (1997)	HS-I	NYSE	9%	62%	29%	
	HS-II	NYSE	10%	69%	21%	
Brockman and Chung (1999)	LSB	SEHK	33%	45%		21%

Notes: Glosten and Harris (1988)(GH) decompose the spread into transitory and permanent components. The permanent component is the adverse selection cost. The transitory component represents order processing cost and inventory holding cost. Stoll (1989) decomposes the spread into order processing cost, adverse selection, and inventory holding cost components. Under the assumption of zero inventory holding cost, George, Kaul, and Nimalendran (1991) (GKN) decompose the spread into order processing cost and adverse selection components. Masson (1993) decomposes the spread into realized and permanent components. The realized component represents order processing cost and the permanent component is the adverse selection cost, while the inventory holding cost is set to be zero. Under considering the interaction between adverse selection component and inventory holding cost, McDonald (1994) decomposes the bid-ask spread into order processing cost, adverse selection, and inventory holding cost components. Lin, Sanger, and Booth (1995) (LSB) decompose the spread into order processing cost and adverse selection components, as well as estimate a measure of order persistence. The inventory holding cost is set to be zero. In Porter and Weaver's (1996) study, the maximum values of estimated adverse selection components are presented here. Estimated order processing components are simply one minus the adverse selection components. Madhavan, Richard, and Rooms (1997) (MRR) construct a model to analyze intraday price formation. The adverse selection cost and the transaction cost, which reflects order processing cost and inventory holding cost, can be estimated from this model. Huang and Stoll (1997) (HS) construct a three-way decomposition model to decompose the spread into three components. Their model has two extended forms based on serial correlation in trade flows (denoted as HS-I) and based on trading pressure (denoted as HS-II). SEHK is a name in its abbreviated form of the Stock Exchange of Hong Kong. The number of order processing cost component includes inventory holding cost component for GH and MRR methods.

Table II

Summary Statistics for Sample Contracts

ıres	MSCI Taiwan index futures				
Standard deviation	Mean	Median	Standard deviation	Equality test	
0.0058%	0.0575%	0.0551%	0.0127%	Mean equality test	t-value = -31.318*
0.653	0.180	0.169	0.039	Mean equality test	t-value = 192.707*
1495.0	315.3	319.7	38.9	Mean equality test	t-value = 226.749*
1.5834%	0.0192%	-0.0711%	2.1518%	Variance equality test	F-value = 1.847*
6756	6171	6002	2163	Mean equality test	t-value = 39.492*
391	1307	1328	382	Mean equality test	t-value = 17.275*
8.881	4.909	4.538	1.873	Mean equality test	t-value = 16.525*

er 31, 1999. After excluding incomplete trading days and last trading days, there are 466 trading days for the Nikkei 225 index futures and 507
e relative spread at time t is $2 | Z_t | = 2 | \log(P_t / Q_t) |$ and the effective dollar spread at time t is $2 | P_t - Q_t |$, where Q_t denotes the quote
ce at time t; B_t denotes the bid price at time t; and P_t denotes the transaction price at time t. The daily average effective relative spread, daily
are calculated across all trades in a trading day. The daily return is $\log(P_d)-\log(P_{d-1})$, where P_d denotes the closing transaction price at day d.
livided by trade number. '*' denotes significance at the 1% level.

Table III

Daily Decomposition Results

	Nikkei 225 stock index futures contract	MSCI Taiwan stock index futures contract
Order processing cost component		
Average estimated γ	0.2969	0.3915
Average t-statistic on γ	6.9395	8.7285
Average R-squared	0.0522	0.0616
Number of days with γ >0 and t-statistic significant at 0.01 level	458	501
Average order processing spread	0.0112%	0.0223%
Mean equality test on γ	t-value=-15.9277 (p-value=0.0000)	
Mean equality test on order processing spread	t-value=-30.5480 (p-value=0.0000)	
Adverse selection component		
Average estimated λ	0.4117	0.3949
Average t-statistic on λ	12.4889	12.4903
Average R-squared	0.1236	0.1188
Number of days with λ >0 and t-statistic significant at 0.01 level	466	502
Average adverse selection spread	0.0156%	0.0226%
Mean equality test on λ	t-value=3.7994 (p-value=0.0001)	
Mean equality test on adverse selection spread	t-value=-21.1511 (p-value=0.0000)	
Order persistence		
Average estimated θ	0.2914	0.2136
Average t-statistic on θ	7.3588	7.6812
Average R-squared	0.0356	0.0519
Number of days with θ >0 and t-statistic significant at 0.01 level	462	495
Mean equality test on θ	t-value=15.9168 (p-value=0.0000)	

Notes: The sample period is from January 1, 1998 to December 31, 1999, and there are 466 trading days for the Nikkei 225 index futures and 507 trading days for the MSCI Taiwan index futures. The following regression models (according to Lin, Sanger, and Booth's (1995) methodology) are used to estimate the spread components for each trading day:

$$Q_{t+1} - Q_t = \text{ª} Z_t + e_{t+1} \quad (1)$$

$$Z_{t+1} = \text{¯} Z_t + \text{¦}_{t+1} \quad (2)$$

$$P_{t+1} - P_t = -\text{¥} Z_t + u_{t+1} \quad (3)$$

where Q_t denotes the quote midpoint at time t, i.e. $Q_t = (A_t+B_t)/2$; A_t denotes the ask price at time t; B_t denotes the bid price at time t; $Z_t = P_t - Q_t$ is one-half the signed effective spread at time t (with $Z_t < 0$ for a sell order and $Z_t > 0$ for a buy order); P_t denotes the transaction price at time t; λ is the adverse selection component; θ is the order persistence that reflects the tendency of a buy (sell) order following a buy (sell) order; $\gamma = 1 - \lambda - \theta$ is the order processing cost component; and e_t, η_t, u_t are normally distributed error terms. The logarithms of the transaction price (P_t) and the quote midpoint (Q_t) are used here. The effective relative spread at time t is $2 | Z_t |$. For each trading day, the order processing spread can be computed as γ times mean effective relative spread and the adverse selection spread can be computed as λ times mean effective relative spread.

omponent, Adverse Selection Component, and Order Persistence by Time of the
ontract

onent	Adverse selection component				Order persistence			
Number of days with γ >0 and t-statistic significant at 0.01 level	average estimated λ	average t-statistic on λ	average R-squared	Number of days with λ >0 and t-statistic significant at 0.01 level	average estimated θ	average t-statistic on θ	average R-squared	Number of days with θ >0 and t-statistic significant at 0.01 level
366	0.4129	2.9339	0.1489	369	0.1976	2.4050	0.0647	316
395	0.4421	4.5855	0.2008	464	0.2333	3.2663	0.0690	379
374	0.4394	4.3250	0.2076	455	0.2437	2.6217	0.0676	292
337	0.4498	4.2039	0.2113	460	0.2518	2.6869	0.0669	330
335	0.4438	4.0758	0.2004	458	0.2675	3.0038	0.0687	324
275	0.4171	2.8654	0.2006	420	0.2717	3.6229	0.0657	358
234	0.4363	2.9817	0.2075	414	0.2944	4.1214	0.0701	367
374	0.4151	3.8347	0.2009	456	0.2535	3.4935	0.0557	325
354	0.4195	3.6907	0.2063	449	0.2544	2.8167	0.0649	291
313	0.4216	3.5698	0.2077	450	0.2866	3.1527	0.0729	345
283	0.4431	3.7486	0.2173	450	0.3033	3.9639	0.0685	366
284	0.4435	3.9703	0.2079	455	0.2960	4.0466	0.0632	337
312	0.4415	4.2461	0.1933	458	0.2999	3.2985	0.0655	282
406	0.4146	2.2772	0.1729	454	0.2201	2.2153	0.0475	267
	28.0736*	(d.f.=13,6391)			13.9382*	(d.f.=13,6391)		

ecember 31, 1999. After excluding incomplete trading days and last trading days, there are 466 trading days for the Nikkei 225 mber is below thirty are eliminated and 6,405 time intervals remain. Lin, Sanger, and Booth's (1995) methodology is used to persistence (θ) for each time interval (see the note of Table III). The average estimate, average t-statistic, and average R-squared interval are calculated across trading days. '*' denotes significance at the 1% level.

omponent, Adverse Selection Component, and Order Persistence by Time of the Day

tract

t	Adverse selection component				Order persistence			
umber of s with γ>0 l t-statistic nificant at .01 level	average estimated λ	average t-statistic on λ	average R-squared	Number of days with λ>0 and t-statistic significant at 0.01 level	average estimated θ	average t-statistic on θ	average R-squared	Number of days with θ>0 and t-statistic significant at 0.01 level
331	0.3949	4.0579	0.0960	374	0.1873	2.7268	0.0583	262
449	0.3969	5.6492	0.1496	495	0.1771	2.5556	0.0443	258
425	0.4164	5.5064	0.1608	495	0.1759	2.3407	0.0437	245
402	0.4097	5.2143	0.1586	488	0.1771	2.2771	0.0462	229
396	0.4220	5.4130	0.1631	496	0.1970	2.6041	0.0533	264
393	0.4154	5.5873	0.1604	488	0.2034	2.7995	0.0551	288
452	0.3680	5.1326	0.1360	490	0.1685	2.2732	0.0418	234
	12.1192*	(d.f.=6,3532)			5.3396*	(d.f.=6,3532)		

cember 31, 1999. After excluding incomplete trading days and last trading days, there are 507 trading days for the MSCI Taiwan mber is below thirty are eliminated and 3,539 time intervals remain. Lin, Sanger, and Booth's (1995) methodology is used to persistence (θ) for each time interval (see the note of Table III). The average estimate, average t-statistic, and average R-squared e interval are calculated across trading days. '*' denotes significance at the 1% level.

ıg Spread for the Nikkei 225 Stock Index Futures Contract

Scheffe multiple comparisons for order processing spread across time intervals

7:55-8:15	8:15-8:40	8:40-9:05	9:05-9:30	9:30-9:55	9:55-10:15	11:15-11:35	11:35-12:00	12:00-12:25	12:25-12:50	12:50-13:15	13:15-13:40	13:40-14:05	14:05-14:25
	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+
- (*)		+	+	+	+	+	-	+	+	+	+	+	- (*)
- (*)	-		+	+	-	+	-	-	+	+	+	+	- (*)
- (*)	-	-		+	-	-	-	-	-	+	+	+	- (*)
- (*)	-	-	-		-	-	-	-	-	+	+	+	- (*)
- (*)	-	+	+	+		+	-	-	+	+	+	+	- (*)
- (*)	-	-	+	+	-		-	-	+	+	+	+	- (*)
- (*)	+	+	+	+	+	+		+	+	+ (*)	+	+	- (*)
- (*)	-	+	+	+	+	+	-		+	+	+	+	- (*)
- (*)	-	-	+	+	-	-	-	-		+	+	+	- (*)
- (*)	-	-	-	-	-	-	- (*)	-	-		-	-	- (*)
- (*)	-	-	-	-	-	-	-	-	-	+		-	- (*)
- (*)	-	-	-	-	-	-	-	-	-	+	+		- (*)
-	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	

ecember 31, 1999. After excluding incomplete trading days and last trading days, there are 466 trading days for the Nikkei 225 ıber is below thirty are eliminated and 6,405 time intervals remain. The effective relative spread at time t is 2 | Z_t | = 2 | log(P_t ıted by all transactions for each time interval of a trading day. Then, the order processing spread is computed as order processing ıd for each time interval. The mean and standard deviation of order processing spread for each time interval are computed across ion Spread for the Nikkei 225 Stock Index Futures Contract

Scheffe multiple comparisons for adverse selection spread across time intervals

	7:55-8:15	8:15-8:40	8:40-9:05	9:05-9:30	9:30-9:55	9:55-10:15	11:15-11:35	11:35-12:00	12:00-12:25	12:25-12:50	12:50-13:15	13:15-13:40	13:40-14:05	14:05-14:25
		+	+ (*)	+ (*)	+	+ (*)	+	+ (*)	+ (*)	+ (*)	+	+	+	+
	-		+	+	+	+	-	+	+	+	-	-	-	+
	- (*)	-		-	-	+	- (*)	+	+	+	-	-	-	-
	- (*)	-	+		+	+	-	+	+	+	-	-	-	-
	-	-	+	-		+	-	+	+	+	-	-	-	-
	- (*)	-	-	-	-		- (*)	+	+	+	-	-	-	-
	-	+	+ (*)	+	+	+ (*)		+ (*)	+ (*)	+ (*)	+	+	+	+
	- (*)	-	-	-	-	-	- (*)		-	-	-	-	- (*)	-
	- (*)	-	-	-	-	-	- (*)	+		-	-	-	- (*)	-
	- (*)	-	-	-	-	-	- (*)	+	+		-	-	-	-
	-	+	+	+	+	+	-	+	+	+		-	-	+
	-	+	+	+	+	+	-	+	+	+	+		-	+
	-	+	+	+	+	+	-	+ (*)	+ (*)	+	+	+		+
	-	-	+	+	+	+	-	+	+	+	-	-	-	

ecember 31, 1999. After excluding incomplete trading days and last trading days, there are 466 trading days for the Nikkei 225
ıber is below thirty are eliminated and 6,405 time intervals remain. The effective relative spread at time t is $2 \mid Z_t \mid = 2 \mid \log(P_t$
ıted by all transactions for each time interval of a trading day. Then, the adverse selection spread is computed as adverse selection
or each time interval. The mean and standard deviation of adverse selection spread for each time interval are computed across

ng Spread for the MSCI Taiwan Stock Index Futures Contract

ion	Scheffe multiple comparisons for order processing spread across time intervals							
	Time interval	8:45-9:15	9:15-9:45	9:45-10:15	10:15-10:45	10:45-11:15	11:15-11:45	11:45-12:15
	8:45-9:15		+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)
	9:15-9:45	- (*)		+	+	+ (*)	+	-
	9:45-10:15	- (*)	-		+	+	+	- (*)
	10:15-10:45	- (*)	-	-		+	+	- (*)
	10:45-11:15	- (*)	- (*)	-	-		-	- (*)
	11:15-11:45	- (*)	-	-	-	+		- (*)
	11:45-12:15	- (*)	+	+ (*)	+ (*)	+ (*)	+ (*)	

)

cember 31, 1999. After excluding incomplete trading days and last trading days, there are 507 trading days for the Taiwan MSCI
nber is below thirty are eliminated and 3,539 time intervals remain. The effective relative spread at time t is 2 l Z_t l = 2 l log(P_t
ited by all transactions for each time interval of a trading day. Then, the order processing spread is computed as order processing
nd for each time interval. The mean and standard deviation of order processing spread for each time interval are computed across

ion Spread for the MSCI Taiwan Stock Index Futures Contract

Scheffe multiple comparisons for adverse selection spread across time intervals

ion	Time interval	8:45-9:15	9:15-9:45	9:45-10:15	10:15-10:45	10:45-11:15	11:15-11:45	11:45-12:15
	8:45-9:15		+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)
	9:15-9:45	- (*)		-	+	-	-	+
	9:45-10:15	- (*)	+		+	-	-	+ (*)
	10:15-10:45	- (*)	-	-		-	-	+
	10:45-11:15	- (*)	+	+	+		-	+ (*)
	11:15-11:45	- (*)	+	+	+	+		+ (*)
	11:45-12:15	- (*)	-	- (*)	-	- (*)	- (*)	

)

cember 31, 1999. After excluding incomplete trading days and last trading days, there are 507 trading days for the Taiwan MSCI
ıber is below thirty are eliminated and 3,539 time intervals remain. The effective relative spread at time t is 2 | Z_t | = 2 | log(P_t
ted by all transactions for each time interval of a trading day. Then, the adverse selection spread is computed as adverse selection
or each time interval. The mean and standard deviation of adverse selection spread for each time interval are computed across

ive Spread for the Nikkei 225 Stock Index Futures Contract

Scheffe multiple comparisons for relative spread across time intervals

7:55-8:15	8:15-8:40	8:40-9:05	9:05-9:30	9:30-9:55	9:55-10:15	11:15-11:35	11:35-12:00	12:00-12:25	12:25-12:50	12:50-13:15	13:15-13:40	13:40-14:05	14:05-14:25
	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)
- (*)		+	+	+	-	- (*)	+	+	+	+	-	-	-
- (*)	-		+	-	-	- (*)	-	-	-	-	-	- (*)	- (*)
- (*)	-	-		-	-	- (*)	-	-	-	-	-	- (*)	- (*)
- (*)	-	+	+		-	- (*)	-	+	-	-	-	-	- (*)
- (*)	+	+	+	+		- (*)	+	+	+	+	-	-	-
- (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)		+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+	+
- (*)	-	+	+	+	-	- (*)		+	-	-	-	-	- (*)
- (*)	-	+	+	-	-	- (*)	-		-	-	-	-	- (*)
- (*)	-	+	+	+	-	- (*)	+	+		-	-	-	- (*)
- (*)	-	+	+	+	-	- (*)	+	+	+		-	-	-
- (*)	+	+	+	+	+	- (*)	+	+	+	+		-	-
- (*)	+	+ (*)	+ (*)	+	+	-	+	+	+	+	+		-
- (*)	+	+ (*)	+ (*)	+ (*)	+	-	+ (*)	+ (*)	+ (*)	+	+	+	

ecember 31, 1999. After excluding incomplete trading days and last trading days, there are 466 trading days for the Nikkei 225 ıber is below thirty are eliminated and 6,405 time intervals remain. The effective relative spread at time t is 2 | Z_t | = 2 | log(P_t each time interval of a trading day is calculated by all transactions. Finally, the mean and standard deviation of effective relative g days. '*' denotes significance at the 1% level.

ive Spread for the MSCI Taiwan Stock Index Futures Contract

Scheffe multiple comparisons for effective relative spread across time intervals

ion	Time interval	8:45-9:15	9:15-9:45	9:45-10:15	10:15-10:45	10:45-11:15	11:15-11:45	11:45-12:15
	8:45-9:15		+ (*)	+ (*)	+ (*)	+ (*)	+ (*)	+ (*)
	9:15-9:45	- (*)		+	+	+	+	+
	9:45-10:15	- (*)	-		+	+	-	-
	10:15-10:45	- (*)	-	-		-	-	-
	10:45-11:15	- (*)	-	-	+		-	-
	11:15-11:45	- (*)	-	+	+	+		+
	11:45-12:15	- (*)	-	+	+	+	-	

)

cember 31, 1999. After excluding incomplete trading days and last trading days, there are 507 trading days for the Taiwan MSCI ıber is below thirty are eliminated and 3,539 time intervals remain. The effective relative spread at time t is $2 | Z_t | = 2 | \log(P_t$ each time interval of a trading day is calculated by all transactions. Finally, the mean and standard deviation of effective relative g days. ‘*’ denotes significance at the 1% level.

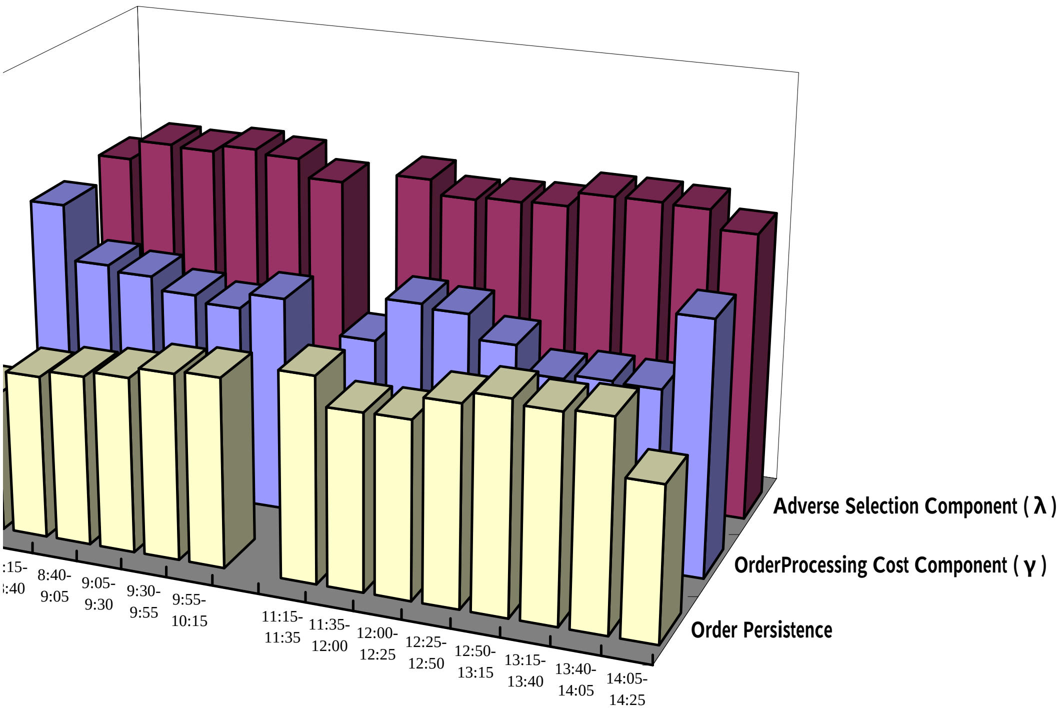

Figure 1

processing cost component, adverse selection component, and order persistence by time of the day for the Nikkei 225 stock index futures contract

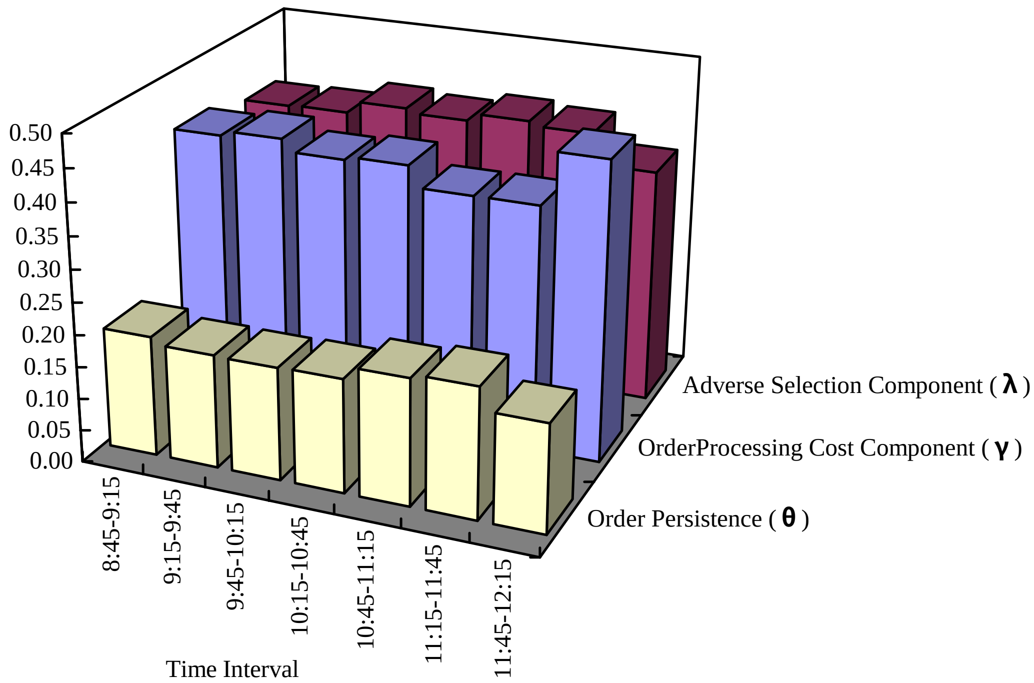

Figure 2
processing cost component, adverse selection component, and order persistence by time of the day for the MSCI Taiwan stock index futures contract

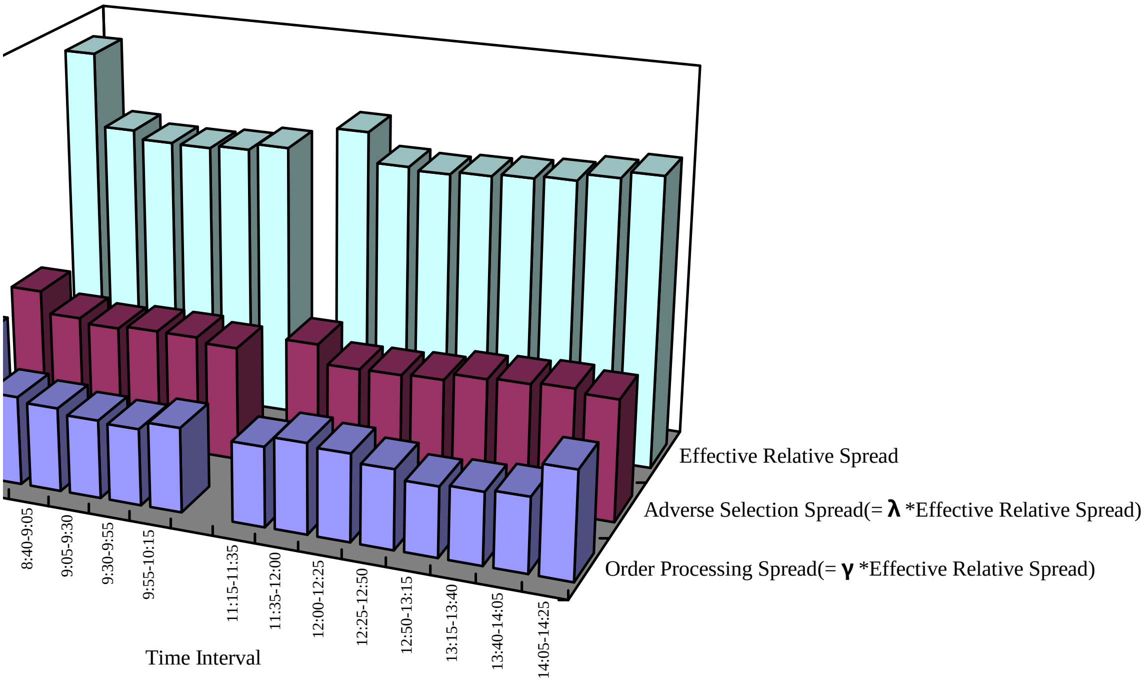

Figure 3

processing spread, adverse selection spread, and effective relative spread by time of the day for the Nikkei 225 stock index futures contract

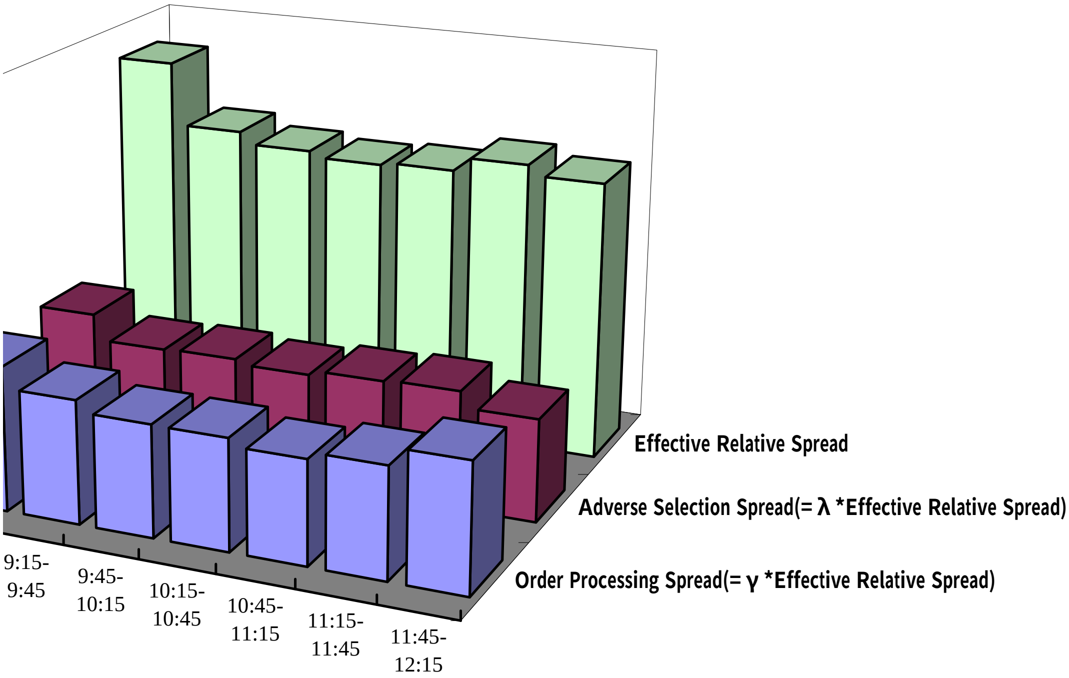

Figure 4

processing spread, adverse selection spread, and effective relative spread by time of the day for the MSCI Taiwan stock index futures contract