How Electronic Trading Affects Bid-ask Spreads and Arbitrage Efficiency between Index Futures and Options

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Abstract

This paper examines the impact of switching to electronic trading on the relative pricing efficiency of Hang Sang Index futures and options contracts traded on the Hong Kong exchange. The study is motivated by the recent shift in 2000 from the pit to an electronic trading platform. Electronic trading leads to lower bid-ask spreads and less price clustering than floor trading in both the options and futures markets. Mispricing between futures and options drops significantly after the change. Quicker correction of mispricing indicates a significant improvement in dynamic inter-market arbitrage efficiency with electronic trading.

INTRODUCTION

Futures and options exchanges worldwide are increasingly shifting from conventional open outcry markets to electronic trading. For example, the London International Financial Futures and Options Exchange (LIFFE) completed its transformation from open outcry to electronic trading in November 2000. Electronic trading eliminates the costs of maintaining a physical site for floor trading. Abolishing pit trading also removes the potential constraint of space for trading activities, and allows exchange participants direct access to the market through computers connected to the trading system of the exchange. Electronic trading also enables real-time exchange risk management against the exposure of market participants.

Computerized trading requires an open limit order book, which enhances market transparency and provides continuous updating and dissemination of information. This change with speedy execution of orders onscreen should make markets more competitive, although in some cases electronic trading may impede efficiency. Because it is hard to withdraw or change limit orders in dynamic market conditions, screen-based trading offers free options to informed traders. Hence, traders reduce order size to limit the cost of adverse selection. This may reduce the market depth and widen bid-ask spreads under volatile market conditions. Therefore, whether electronic trading enhances market efficiency is an empirical question.

Several authors have examined the impact of electronic trading on market liquidity and the bid-ask spread, as well as on its information discovery role. Taylor, van Dijk, Franses, and Lucas (2000), for example, examine how switching to electronic trading affected the cost of arbitrage and dynamic efficiency between FTSE 100 index futures and the cash index. Our study is motivated by the 2000 decision of the Hong Kong Exchanges and Clearing Limited (HKEx) to shift the trading of Hang Seng Index (HSI) futures and options from the pit to an electronic platform. We examine how and to what extent the change affected the static and dynamic arbitrage pricing efficiency of the two markets. We also explore how the change affected the securities' bid-ask spreads and clustering patterns.

Bid-ask spreads are tightened with electronic trading. Spreads cluster at multiples of five ticks in the open-outcry market, but are evenly distributed over from one to five ticks in the electronic trading platform. These results indicate that market making and trading become more competitive under electronic trading. Ex-post observed pricing errors between the options and futures are significantly reduced. The time lag before an observed pricing error disappears also has shortened significantly. The results show that electronic trading has improved both the static and the dynamic efficiency of the market.

LITERATURE REVIEW

In open-outcry trading, orders are relayed to a broker's representative on the trading floor, who then rushes into the pit for order execution. This delays the execution process. Price reporting under open outcry requires manual entry of price information into the computer; which creates a time lag between a trade or a quote and the broadcast of the information. Hasbrouck and Sosebee (1992) show that the average reporting lag for trades on the New York Stock Exchange is around 20 seconds and can be as long as 2 minutes. Time lags like this become critical in volatile market conditions. Moreover, under open outcry, trader quotes may become stale if they are not immediately executed, and market depth information is not available. A screen-based trading system provides price and liquidity information on a real-time basis through an electronic open limit order book that is visible to every market participant. Domowitz (1990) therefore argues that electronic trading improves market transparency and enhances price discovery.

Quotes under electronic trading are firm commitments until they are lifted or cancelled. Orders can be directly routed to the trading system by keying them in on trading terminals or automatically through computer feeds. Trades are confirmed almost instantaneously, which allows traders to revise orders if necessary. As Kumar and Seppi (1994) note that price and quantity uncertainty are major obstacles to arbitrage, electronic trading largely eliminates such risk for arbitrageurs.

Improvement in market transparency and execution efficiency should enhance the competitiveness of the market. A competitive market would offer a narrower bid-ask spread. Tse and Zabotina (2001) find that the spread on the FTSE 100 was reduced from 0.0315% to 0.0244% after computerized trading of the contract began on May 10, 1999. During an earlier period, Frino, McInish, and Toner (1998) report that the spread for the Bund futures contract is lower on the electronic-trading Deutsche Terminborse (DTB) than on the open-outcry LIFFE. They also find that volatility affects the spread more on the DTB than on LIFFE.

Pirrong (1996) notes that locals in a trading pit may be able to tacitly collude to the disadvantage of customers who need to buy and sell large quantities instantaneously. Collusion would be possible because traders interact repeatedly, and defecting would likely result in punishment. Price clustering is also consistent with the negotiation hypothesis of Harris (1991) that in periods of high trading activity and for small trades, traders eliminate odd quotes to minimize the cost of negotiations. Tse and Zabotina (2001) and Gwilym and Alibo (2003) find that transition from open outcry to an electronic trading system for the FTSE 100 Index futures contracts caused a significant reduction in price clustering.

A number of articles have compared relative information discovery between floor and computerized trading. Grunbichler, Longstaff, and Schwartz (1994) find that the computer-traded DAX futures lead the cash stocks by nearly 20 minutes. This is a long lead-time compared to the five minutes typically seen in the U.S. markets, where both the futures and the cash stocks are floor-traded. (See also Stoll and Whaley, 1990.) These results led Grunbichler et al to conclude that electronic trading enhances the speed of price discovery. Martens (1998) finds there is less trading of the Bund futures contract on LIFFE than on the DTB in volatile periods, but the trades on LIFFE become more informative. At the same time, the DTB provides better price discovery with less volume in quiet periods. Fung, Lien, Tse, and Tse (2004) find that the information share of the HSI futures increased relative to the underlying cash index after the futures switched from floor to electronic trading .

Taylor et al. (2000) investigate the effect of the introduction of SETS – an electronic trading system that allows computerized trading of the FTSE 100 stocks on arbitrage efficiency between the FTSE 100 futures and the cash index. Application of a smooth transition error correction model reveals that the change increased the speed of error correction, especially on the cash stock index. This finding supports the idea that electronic trading reduces transaction costs and enhances arbitrage.

This simultaneous shift from floor to electronic trading of Hang Seng Index futures and options lets us test how and to what extent such a change affects static and dynamic arbitrage pricing efficiency between the two markets. To mitigate model and parameter estimation risks in

Black-Scholes pricing models, we adopt a parameter-free put-call-futures price parity condition. We test the effect of the change on the bid-ask spread and its clustering pattern, and use regression analysis to test the effect of market volatility on the performance of the two trading systems.

Our data set supplies complete transaction and bid/ask quotes data. The transaction price data provide actual ex-post trading information and the quote data reflect the efficiency and speed in quote adjustments. We factor in realistic estimates of transaction costs for exchange participants (EPs) or members and non-exchange participants (NEPs) or non-members in order to control for any effect due to variations in trading costs over the sample period.

PUT-CALL-FUTURES PARITY MODEL

For European options and futures contracts that are written against the same underlying asset and share the same expiration day, the arbitrage-free or "fair" value of a futures contract (F^*) should satisfy the following parity relationship:[1]

$$F^* = X + (C - P)(1+ r)^{T-t}, \qquad (1)$$

[1] See Lee and Nayer (1993) for a proof of the parity condition. Fung and Draper (1999) show that the relationship is independent of the difference in contract multipliers between the options and futures contracts. If the clearing house adopts a futures-style margining method for option positions, and if interest-bearing securities represent allowable margin collateral, then the opportunity cost of margin for the futures and options positions will be zero. In this case, the parity condition can be simplified as $F^*=X+C–P$ (Duan and Zhang, 2001). The case in Hong Kong lies somewhat in between. HKEx adopts futures-style margining for option positions, but a "haircut" is imposed on any form of margin deposits. Hence, both the bought and written option positions, as well as the futures position, are subject to financing costs for arbitrageurs. We factor in a realistic financing cost of the required margin for establishing the options and futures legs of the arbitrage portfolio. Fung and Fung (1997) view the haircut as an interest rate differential.

where C and P are the synchronous prices of the call and put options contracts on day t that share a common exercise price X, the same underlying asset as for the futures contract, and identical expiration date T (T and t are in fractions of a year). r is the riskless rate of interest for the holding period T-t.

Deviations from the parity relationship represent potential arbitrage opportunities. If the actual futures price F is higher (lower) than F^*, an arbitrageur can short (long) the over-priced futures contract and simultaneously hedge the position by buying (shorting) the call and shorting (buying) the put. The arbitrage opportunities using futures and options avoid many of the problems associated with arbitraging between the cash index and its futures or options. These problems include (1) high transaction cost in trading stocks, (2) institutional restrictions against short-selling of stocks, and (3) uncertainty over future dividend payments. Finally, for Asian-style options and futures that settle against an average of the index, directly arbitraging between them eliminates the risk and the cost of unloading the stock leg of the arbitrage trade (Fung and Draper, 1999).

When there are transaction costs, the deviation of the actual futures price from its fair value has to exceed the transaction cost to trigger arbitrage. Hence, the actual futures price can fluctuate between no-arbitrage bounds that are determined by the cost of transaction. The upper no-arbitrage bound can be written as $F^U = (C - P) + X + M$, and the lower no-arbitrage bound as $F^L = (C - P) + X - M$, where F^U and F^L denote the upper and lower no-arbitrage bounds for the futures price. M denotes the total round-trip cost for establishing and unloading the arbitrage portfolio.

An arbitrage opportunity occurs when the actual futures price is above the upper no-arbitrage bound (i.e., overpricing) or below the lower no-arbitrage bound (i.e., underpricing). Let e denote a signed pricing error; then $e = F - F^U; F > F^U$ or $= F - F^L; F^L > F$. An upper bound violation is positively signed, and a lower bound violation is negatively signed. The statistical distribution of e reveals the characteristics of the futures prices surrounding the no-arbitrage boundaries.[2] The extent of any overpricing is defined as $e^+ = F - F^U; F > F^U$, while the extent of an underpricing is defined as $e^- = F^L - F; F^L > F$. Ignoring the direction of the mispricing, the magnitude of the error is equal to $|e| = e^+; F > F^U$ or $= e^-; F^L > F$.

Factoring the difference between bid and ask prices, we modify the tests as follows. To test for an overpricing of the futures contract, we compare the bid futures price quote (F_Q^B) with the no-arbitrage upper bound (F_Q^U) that is based on options quotes. $F_Q^U = X + (C_Q^A - P_Q^B) + M$; where C_Q^A and P_Q^B are the synchronous ask and bid price quotes for the call and put options contracts. Similarly, to test for an underpricing of the futures contract, we compare the ask futures price quote (F_Q^A) with the no-arbitrage lower bound (F_Q^L). $F_Q^L = X + (C_Q^B - P_Q^A) - M$; where C_Q^B and P_Q^A are the bid and ask price quotes for the call and put options contracts.

TEST HYPOTHESES, DATA, AND METHODOLOGY

Hang Seng Index futures were introduced in May 1986 and options in March 1993. They were traded in open outcry in adjacent pits and then from June 5, 2000, onward, on the same electronic

[2] In the benchmark case of zero transaction cost, the distribution of e describes the deviation of the futures price from its fair value.

platform, the Hong Kong Futures Automatic Trading System (HKATS). As Fung and Mok (2001) note, the difficulty in conducting arbitrage lies mainly in executing the options leg of the trade in floor trading. An option quote may become stale quickly if it is not acted on. Stale prices are a minor problem in futures trading because of the very liquid market. The option market maker may simply cry out "not held" when a trader tries to lift a quote. This protects the market maker against exploitation in fast-changing market conditions, and allows revised quotes in its favor. Since the advance of electronic trading, the open limit order book posts firmly committed bids and asks for up to 250 prices on both sides. HKATS accepts only limit orders. The system matches trades following strict price and time priority. Instantaneous trade confirmation allows traders and investors to immediately cancel an order or to revise it at different prices if necessary to complete their portfolios.

Since HKATS provides convenient and direct access to the market and reduces costs to traders for a physical presence on the floor, it is logical to expect tighter bid-ask spreads in the futures and options markets. A more competitive marketplace should also result in less clustering of the spread. Lower bid-ask spread, improved market transparency, and efficient execution should enhance both static and dynamic arbitrage efficiencies between the two markets. With the institution of electronic trading, we would expect pricing errors to be reduced and observed mispricings to dissipate more quickly than under floor trading. Our study tests the hypotheses:

H1: Electronic trading leads to lower bid-ask spreads and less price clustering than floor trading.

H2. Pricing errors are closer to zero under electronic than under floor trading.

H3. Pricing errors are eliminated more quickly under electronic trading than under open outcry.

H4: The relative performance of the trading systems depends on market volatility.

Data

Hang Seng Index (HSI) futures and options contracts are both written on the Hang Seng Index, the benchmark index of the Hong Kong market. The HSI is a value-weighted index composed of 33 blue-chip stocks that constitute over 70% of the total Hong Kong market capitalization. Contract months for HSI futures are the spot month, the next calendar month, and the next two quarterly months. Contract months for the options are spot month, the next two calendar months, the next three quarterly months, and the next two months of June and December. Both futures and options contracts have the same contract multiplier of HK$50 per index point. The spot (current) month contracts of both contracts expire on the same day of the month. The Asian-style settlement methods are identical. Both contracts settle against an arithmetic average of the cash index taken every five minutes on the expiration day. Our study focuses on the spot month futures and options contracts because they are the most liquid until near or on the last trading day (or at expiration). For this reason, we substitute the next month contract for the spot month contract on the last trading day.

To examine the potential impact of the change in microstructure on options-futures pricing behavior, we use the time-stamped, tick-by-tick bid and offer quotes and transaction price records of the Hang Seng Index options and futures contracts obtained from HKEx for the period May 1, 1999, through June 30, 2001. Data for the entire months of May and June 2000 are discarded because there may have been unusual trading behavior surrounding the time of the change in trading platform. Therefore, the sample covers one year of open outcry trading data from May 1, 1999, through April 30, 2000 (247 days), and one year of electronic trading data from July 1, 2000, through June 30, 2001 (245 days).

We use only the currently refreshed quotes. An updated entry of a particular (options or futures) contract occurs when there is a change in the quote. This procedure largely eliminates any problem due to use of stale prices from before the shift to electronic trading. One shortcoming of this approach is that active quotes that had remained unchanged during the particular trading interval are eliminated from the analysis.[3]

Transaction Costs

The total cost of conducting arbitrage is the sum of the financing cost of the margin deposit, trading cost, and the bid-ask spread. We have previously explained our treatment of the bid-ask spread. Below we lay out our treatment of the financing cost of margin deposits and the explicit trading costs. We differentiate costs for two classes of potential arbitrageurs - members (i.e., so-called exchange participants or EPs) and non-members (i.e., so-called non-EPs) of the exchange.

The clearing arm of the exchange, the Hong Kong Clearing Corporation (HKCC), adopts a futures-style margining method for calculating the margin requirement for option positions. This margining method does not require long premiums to be paid in full by buyers. The premiums are transferred to the option writer in the form of a variation adjustment. The initial margin requirement for EP accounts per put-call-futures arbitrage portfolio is 25 index points (i.e., HK$1,250) of initial margin for each leg of the arbitrage portfolio. This means the initial margin per portfolio is 75 index points, or HK$3,750, throughout the sample period.

The daily marked-to-the-market cash flow for the arbitrage portfolio should be close to zero. Hence, the daily variation margin does not affect our valuation, and the only cost due to

[3] We also use signed transaction data following the Lee and Ready (1991) approach. The results

margin is the opportunity cost of capital for the 75-point initial margin deposit for the EP account per arbitrage portfolio. Cash margin deposits with HKFE are credited with market interest, net of 1.2 percentage points retained by the Exchange.[4] Therefore, the (financing) cost of margin deposits for EPs (M_{EP}) per arbitrage portfolio in terms of the total interest forgone is equal to: M_{EP} = 75 index points $\left[(1+1.2\%)^{T-t}-1\right]$

For non-EPs, a minimum margin is charged against short option positions. The margin has been set since 1996 at 20% of the HSI futures minimum margin for EPs. Upon approval by the exchange, non-EPs are required to deposit, per arbitrage portfolio, only the minimum margin for the short position, varying between 168 and 304 index points. If K represents the actual margin (in index points) on day t, then the opportunity cost of the margin deposit for non-EPs (M_{NEP}) is equal to $K\left[(1+1.2\%)^{T-t}-1\right]$.

In addition to margin cost, EPs have to pay (1) a one-way trading fee of HK$11.5 per trade for each HIS futures and options contracts (HK$10 for an exchange fee; HK$1 for a Securities and Futures Commission (SFC) levy, and HK$0.5 for a Compensation Fund levy); (2) a settlement fee of HK$10 per each HSI futures position that is not closed out before expiration; and (3) an exercise fee of HK$10 on each expired in-the-money option. No charges are levied on expired out-of-the-money options. There has been no change in these transaction costs since July 1, 1994. Therefore, EPs establishing an arbitrage trade for a hold-to-expiration strategy pay one one-way trading fee and one settlement fee for the futures contract, and two one-way trading

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available upon request are consistent with those of the original transaction price data.

[4] At the start of futures contract trading (May 8, 1986), the retention rate was set at 2%. It was lowered to 1.8% on July 1, 1998. The rate was further reduced to 1.2% on January 2, 1999.

fees and one exercise fee for the options portfolio. These amount to HK$54.5, or 1.09 index points over the sample period, given HK$50 per index point.

Non-EP investors must pay commissions in addition to these trading fees. The minimum one-way commission for both futures and options contracts for an overnight trade has been HK$100. Each arbitrage trade involves two one-way commissions for the HSI futures position and (at most) three one-way commissions for the options portfolio (no commission is charged on expired out-of-money options, but another one-way commission is charged for exercising an in-the-money option).[5] Hence, the total commission cost for non-EP investors per arbitrage trade is HK$500, or 10 index points. Overall, the total trading and commission cost for such investors is estimated to be 11.09 index points over the sample period. Hence, the total cost per put-call-futures arbitrage portfolio for EPs is estimated at $11.09+75\left[(1+1.2\%)^{T-t}-1\right]$ and for non-EPs at $11.09+K\left[(1+1.2\%)^{T-t}-1\right]$ index points.

Construction of the Put-Call-Futures Trios

To alleviate the problem of non-synchronous prices, we match the transaction prices of a futures contract and a pair of call and put options that share the same exercise price, all with the same expiration date, within a one-minute interval. No such trio is formed if there is more than one minute in trading time between any two prices. As there are many futures prices that can be matched with an identical options pair within a particular time window, only the put-call-futures pair with the shortest time interval is selected, and the others are discarded. We find a total of

[5] This is a conservative estimate of the option commission cost. Since one option is bought and the next is sold, no commission will be incurred at option expiration if the sold option is in-the-money.

8,277 matched put-call-futures trios for the period before the shift to electronic trading and 13,251 for the period after the shift.

Two separate series of matched trios are created for the quote data, following the same matching criteria as for the transaction data. In the first series, the ask price quote of the futures is matched with the bid price quote of the call and the asked price quote of the put. In the second series, the bid price quote of the futures is matched with the ask price quote of the call and the bid price quote of the put. A total of 38,252 and 3,214,531 put-call-futures trios are obtained in the two consecutive periods. Similar procedures are adopted for the bid-ask identified traded prices, to obtain a total of 3,351 and 7,243 put-call-futures trios for the two comparison periods.

Test of Dynamic Efficiency and Impact of Market Volatility

If electronic trading hastens efficient price adjustment, we would expect mispricing to disappear more quickly after the shift to electronic trading. To examine whether the change in market microstructure has improved dynamic efficiency, we test for how long it takes for each observed mispricing to disappear in the two sample periods.

We also run a number of regressions to test how and to what extent the switch to electronic trading affects the relationships between bid-ask spreads, the pricing errors, and the market volatility.

EMPIRICAL RESULTS

Bid-Ask Spreads

Figures 1 through 3 illustrate the frequency distributions of the absolute quoted bid-ask spreads of the nearby futures, call, and put contracts, respectively, for the open outcry and electronic periods. Figure 1 shows that the spreads of futures contracts in the open outcry market clustered at five ticks (78.1%), followed by ten ticks (16.2%). During the electronic period, the spreads have been much more evenly distributed from one to five ticks (at frequencies of 9.02%, 14.2%, 17.3%, 17.6%, and 16.6%, respectively).

Christie and Schultz (1994) suggest that price clustering is the reason for widening the bid-ask spread in the Nasdaq market. We would expect that the reduced clustering following establishment of electronic trading should result in a narrowing in the spread. Table 1 reports the daily absolute spread and percentage spread. The percentage spread is the equal to the absolute spread divided by the midquote of the bid and ask prices. The daily spread is estimated as the average of all spreads in a day. Panel A shows that the mean (median) of daily absolute spreads dropped significantly from 5.75 (5.57) for open outcry to 4.56 (4.53) for electronic trading. The results of the percentage spreads presented in Panel B are similar. Reductions in bid-ask spreads with the establishment of electronic trading are also consistent with an increased competition resulting from improved market transparency and execution efficiency.

The results for the calls and puts are qualitatively similar to those of the futures. Figures 2 and 3 show that the absolute quoted spreads of calls and puts, respectively, clustered at five and multiple of 10 ticks during open outcry. For the call (put) options market, the frequencies of 5, 10, and 20 ticks are 20.0% (19.4%), 33.2% (32.6%), and 14.1% (12.2%). As in the futures market, spreads are distributed much more evenly over five ticks during the electronic trading period. Table 1 also shows that spreads narrow after the options are transferred to an electronic trading system.

Arbitrage Efficiency between the Futures and Options

Table 2 presents the results of effects on static efficiency using transaction price data. The table summarizes the ex-post arbitrage profits for the overall sample period, and for the periods before and after the shift. It reports results for the three different cost categories – i.e., zero-cost, EP (or member) costs and non-EP (or non-member) costs. We also discuss the results using the bid-ask quote data and bid-ask identified transaction data, but to save space, we do not tabulate these results.

In the zero-cost category in Table 2, the standard deviation of the errors (e) drops from 113.93 index points to 19.08 index points, a decline of 83.3%. This shows that the pricing errors are bunched much more closely to zero for electronic trading than under floor trading. The potential arbitrage profits drops from an average of 40.74 index points to 10.67 index points, a 73.8% decline after switch. The median changes are from 15 to 8 index points, a decline of 46.7%. The results based on EP and non-EP costs and in the other two data sets are similar.

The results based on the bid-ask quote data are more pronounced. The average arbitrage profit drops from 120.21 to 7.37 index points; the median drops from 30 to 4 index points. The result is consistent with Fung and Mok's (2001) finding that quote data over-estimate the magnitude of potential arbitrage profit under the floor trading system. The estimates for potential arbitrage profits are the tightest using the identified transaction prices. The mean profits are estimated at 18.9 index points before and 6.3 index points after the change; the median profits are 15 and 5 index points. The differences in all the pairwise comparisons are statistically significant at the 1% level.[6]

Table 3 presents the results of effects on dynamic efficiency using transaction prices. The table shows summary statistics of the time required for a particular mispricing to disappear. If the arbitrage efficiency of the trading system is improved under an electronic system over floor trading, it should take less time for the market to react and to arbitrage away mispricings.

In the zero-cost category with transactions data in Table 3, the average time for a mispricing to disappear drops from 2,985 to 2,334 seconds, a 21.8% decline, after the shift. The median time drops from 1,721 to 1,067 seconds, a 38.0% decline. The standard deviations also fall. This shows that electronic trading has enhanced the dynamic efficiency of the market, which is reflected in a reduction in the time for correcting observed mispricings. The results based on EP and non-EP costs and in the other two data sets are similar.

The results (not tabulated for brevity) are much more pronounced when the bid-ask quote data are used. The average time for a mispricing to disappear drops from 1,106 to 60 seconds; the median time drops from 58 to 19 seconds. This indicates the extremely high efficiency of the electronic trading system in realigning quotes whenever an error (or potential arbitrage opportunity) is observed.[7] The differences in all the pairwise comparisons are statistically

[6] A two-sample t-test is used to test whether the means are equal between the two sample periods. An F-test indicate whether the ratio of the variances between two periods deviates from unity. The non-parametric Wilcoxon signed rank test is used to test for the equality of the medians. A full summary table for the test statistics is available upon request.
[7] This also indicates the effectiveness of traders using program trading techniques to continuously monitor prices in the two markets.

significant at the 1% level. And when higher trading costs are assumed, mispricings disappear even more quickly.

Effects on the Impacts of Market Volatility

Table 4 summarizes the results of the regression testing the effect of market volatility and the regime change on the futures quote spread. The coefficient for the regime dummy (α_3) is significantly negative. This shows that the quote spread, controlling for other factors, dropped after the advent of electronic trading. Time-to-maturity has no significant impact on the spread either before and after the change. Volatility has a greater impact on the spread with the change to electronic trading. This result is consistent with the free-option problem in electronic trading. Note that the R^2 is over 56%.

Table 5 summarizes the results of the regression testing the effect of market volatility and the regime change on the options spread (in percentage of the middle quote). The coefficient for the regime dummy (β_4) is significantly negative, which indicates that the percentage spread declined after electronic trading. The negative sign for β_1 shows the wide percentage spread when options approached expiration in the floor trading environment. The time-to-maturity variable, β_5, shows that the nearness to expiration effect weakened after the switch, with a reduced percentage spread, especially for options that are close to maturity. β_7 shows that electronic trading reduces the impact of market volatility on options spreads. This result indicates that the increased liquidity of options after electronic trading more than compensates for the negative impact of the free-option problem after the change.

Table 6 summarizes the results of the regression testing the effect of market volatility and the regime change on pricing errors (based on zero-cost). δ_3 is significantly negative, which indicates the shift to electronic trading reduces the average mispricing. δ_4 is also negative, which indicates that electronic trading reduces the impact of time-to-maturity on the extent of pricing errors. Volatility in general, however, has no significant impact on the extent of errors under both trading systems.

Table 7 summarizes the results of the regression testing the effect of market volatility and the regime change on the dynamic efficiency of the markets. ϖ_4 for the quote data is significantly negative. This indicates that electronic trading has accelerated the convergence of options and futures prices over time. ϖ_5 are all negative but not significant. Note the high R^2, 0.25, of the regression for the quote data.

CONCLUSIONS

The shift to electronic trading of the Hang Seng Index futures and options offers an excellent opportunity to examine how the trading environment affects bid-ask spreads and arbitrage efficiency between the index futures and options.

An open limit order book under screen trading provides transparency in the trading process and speedy execution of orders. This makes the market more competitive and results in narrower bid-ask spreads. Spreads are much less clustered in the electronic trading system than under the open outcry system.

Our results on the testing of the price parity relationship between futures and options positions show that the enhanced market transparency and execution efficiency of electronic trading have significantly improved the alignment of index options and futures trading. As a result, parity between actual and synthetic futures prices is strengthened under screen trading. The overall results support the decision of the Hong Kong exchange to switch to electronic trading.

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Table 1.
Daily Bid-Ask Spreads

Market	**Open Outcry**	**Electronic Trading**	**Test Statistic of Equality t-value**
Panel A: Absolute Spread			
Futures			
Mean	5.749	4.558	-20.05
Median	5.569	4.530	-15.10
Calls			
Mean	41.68	6.156	-9.18
Median	22.00	6.042	-18.01
Puts			
Mean	37.44	5.837	-9.82
Median	23.00	5.354	-17.37
Panel B: Percentage Spread			
Futures			
Mean	0.0395	0.0302	-29.44
Median	0.0397	0.0301	-17.93
Calls			
Mean	16.71	5.043	-12.11
Median	12.50	4.322	-14.84
Puts			
Mean	16.46	4.990	-12.54
Median	12.37	4.040	-14.96

Equality of means is tested by the t-test, and medians by the nonparametric Wilcoxon signed rank test.

Table 2
Ex-Post Arbitrage Profit (in index points) Based on Transaction Prices for Spot Month Contract for Overall Sample Period (May 1, 1999 – June 30, 2001*)

		Overall Sample Period Spot Month (May 1, 1999 – June 30, 2001*)				Before Shift Spot Month (May 1, 1999 – April 30, 2000)				After Shift Spot Month (July 1, 2000 – June 30, 2001)			
		N	Mean	Std	Median	N	Mean	Std	Median	N	Mean	Std	Median
Zero-cost[1]	e_T	19,686	0.86	71.13	1.00	7,326	1.57	113.93	2.00	12,360	0.44	19.08	1.00
	$\|e_T\|$	19,686	21.86	67.69	10.00	7,326	40.74	106.41	15.00	12,360	10.67	15.83	8.00
	e_T^+	10,159	22.01	66.66	10.00	3,704	41.84	106.69	15.00	6,455	10.63	10.37	8.00
	e_T^-	9,527	21.69	68.77	10.00	3,622	39.62	106.11	15.00	5,905	10.70	20.18	7.00
EPs[2]	e_T	18,707	0.87	72.62	0.89	7,274	1.57	113.94	1.91	11,433	0.42	19.22	0.89
	$\|e_T\|$	18,707	21.83	69.26	8.89	7,274	39.91	106.73	13.88	11,433	10.33	16.21	6.90
	e_T^+	9,665	21.97	68.17	8.90	3,675	41.05	107.05	13.89	5,990	10.26	10.39	7.83
	e_T^-	9,042	21.68	70.42	8.89	3,599	38.75	106.41	13.87	5,443	10.40	20.81	6.89
Non-EPs[3]	e_T	8,185	1.19	107.72	1.73	4,143	2.30	149.21	3.73	4,042	0.05	26.01	0.86
	$\|e_T\|$	8,185	33.60	102.35	8.85	4,143	56.07	138.29	11.77	4,042	10.56	23.77	6.85
	e_T^+	4,307	33.06	99.22	8.84	2,151	56.21	136.03	9.84	2,156	9.95	11.75	6.85
	e_T^-	3,878	34.20	105.74	8.85	1,992	55.91	140.73	13.66	1,886	11.27	32.44	6.85

*Excluding May and June 2000.

[1] The zero-cost category assumes away all transaction costs and serves as a benchmark case for comparison purpose.

[2] EP are Exchange Participants, who do not incur any commission charges if they trade on their own account.

[3] Non-EP are Non-Exchange Participants, who must trade through EPs and hence incur commission charges for conducting arbitrage.

e_T denotes a pricing error based on transaction prices, $e_T = F_T - F_T^U; F_T > F_T^U$ or $= F_T - F_T^L; F_T^L > F_T$. The subscript T represents transaction prices. F_T , F_T^U , and F_T^L , respectively, stand for the futures price and the no-arbitrage upper and lower bounds. An upper (lower) bound violation produces a positively (negatively) signed error. An overpricing is defined as $e_T^+ = F_T - F_T^U; F_T > F_T^U$, while an underpricing is defined as $e_T^- = F_T^L - F_T; F_T^L > F_T$. Ignoring the direction of the mispricing, the magnitude of a pricing error is equal to $|e_T| = e_T^+; F_T > F_T^U$ or $= e_T^-; F_T^L > F_T$.

Table 3
Summary Statistics of Time for Mispricing to Disappear (in seconds)
Based on Transaction Prices for Spot Month Contract

	Initial Mispricing	Overall Sample Period Spot Month (May 1, 1999 – June 30, 2001*)				Before Shift Spot Month (May 1, 1999 – April 30, 2000)				After Shift Spot Month (July 1, 2000 – June 30, 2001)			
		N	Mean	Std	Median	N	Mean	Std	Median	N	Mean	Std	Median
Zero-Cost[1]	e_T	12,773	2,534.88	3,120.14	1,228.00	3,943	2,984.78	3,325.14	1,721.00	8,830	2,333.98	3,002.62	1,066.50
	e_T^+	6,744	2,588.81	3,151.15	1,278.00	1,956	3,092.25	3,370.48	1,831.50	4,788	2,383.15	3,033.45	1,096.50
	e_T^-	6,029	2,474.55	3,084.23	1,192.00	1,987	2,878.98	3,277.30	1,612.00	4,042	2,275.73	2,965.01	1,035.00
EPs[2]	e_T	12,939	2,250.89	2,947.49	1,027.00	4,348	2,616.43	3,164.94	1,346.00	8,591	2,065.89	2,813.22	905.00
	e_T^+	6,805	2,248.76	2,953.60	1,035.00	2,163	2,665.00	3,260.09	1,372.00	4,642	2,054.81	2,778.50	914.50
	e_T^-	6,134	2,253.26	2,940.94	1,010.50	2,185	2,568.34	3,067.84	1,313.00	3,949	2,078.92	2,853.79	897.00
Non-EPs[3]	e_T	5,901	2,004.14	2,816.12	794.00	2,645	2,303.44	2,945.27	1,069.00	3,256	1,761.00	2,682.67	651.50
	e_T^+	3,161	1,964.77	2,774.81	770.00	1,370	2,436.06	3,046.66	1,176.50	1,791	1,604.27	2,488.67	566.00
	e_T^-	2,740	2,049.55	2,862.88	804.00	1,275	2,160.93	2,826.54	973.00	1,465	1,952.61	2,891.62	734.00

*Excluding May and June 2000.
[1] The zero-cost category assumes away all transaction costs and serves as a benchmark case for comparison purpose.
[2] EPs are Exchange Participants, who do not incur any commission charges if they trade on their own account.
[3] Non-EPs are Non-Exchange Participants, who have to trade through EPs and hence incur commission charges for conducting arbitrage.
The table shows the summary statistics of the time for a particular mispricing to disappear. The sample is restricted to observations that an initial mispricing subsequently absorbed into the no-arbitrage bound or reversed. e_T signifies any initial mispricing occurs on either direction. e_T^+ signifies cases where the initial mispricings were positive; whilst e_T^- represents cases where the initial mispricings were negative.

Table 4
Effect of Time-To-Maturity and Market Volatility on Quote Spread of Futures Prices

	N	α_0	α_1	α_2	α_3	α_4	α_5	R^2	Adj R^2	F
Futures Absolute Spread	490	5.692	0.003	0.083	-3.165	0.009	10.888	0.5632	0.5587	125.08***
	(t-value)	(67.48)***	(0.54)	(0.67)	-(15.19)***	(0.98)	(10.74)***			

*significant at 10% level.
**significant at 5% level .
***significant at 1% level.

Model:

$$\text{Spread} = \alpha_0 + \alpha_1 TTM + \alpha_2 Volatility + \alpha_3 D + \alpha_4 DTTM + \alpha_5 DVolatility + \varepsilon_t$$

where
TTM denotes time-to-maturity of the contract;
volatility represents the log difference of day high and day low of the spot month futures contract; and
D is a dummy variable that separates the period before and after the change, where D=0 before shift and D=1 after shift.

Table 5
Regression of Variables with Options Percentage Spread for Spot Month Contract

	N	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	R^2	Adj R^2	F
Options Percentage Spread	11,834	15.787	-0.734	183.694	4.616	-8.747	0.315	-3.637	-119.673	0.1056	0.1050	199.41***
	(t-value)	(25.05)***	-(14.50)***	(19.77)***	(4.20)***	-(6.30)***	(4.40)***	-(0.59)	-(8.40)***			

*significant at 10% level.
**significant at 5% level .
***significant at 1% level.

Model:

$$\text{Percentage Spread} = \beta_0 + \beta_1 TTM + \beta_2 \left|\frac{F-X}{X}\right| + \beta_3 Volatility + \beta_4 D + \beta_5 DTTM + \beta_6 D\left|\frac{F-X}{X}\right| + \beta_7 DVolatility + \varepsilon_t$$

where
Percentage spread is equal to the absolute value of the bid-ask spread divided by the middle quote; TTM is the time to maturity of the contract; $\left|\frac{F-X}{X}\right|$ is a proxy for the moneyness of the option, Volatility represents the log difference of day high and day low of the spot month futures contract; and D is a dummy variable that separates the two periods before and after the change, where D=0 before shift and D=1 after shift

Table 6
Impact of Time-to-Maturity and Volatility on Pricing Errors (based on Zero-Cost)

	N	δ_0	δ_1	δ_2	δ_3	δ_4	δ_5	R^2	Adj R^2	F
Transaction Prices Data	452	22.687	1.450	0.422	-18.438	-1.387	18.053	0.2938	0.2859	37.19***
	(t-value)	(6.26)***	(5.12)***	(0.08)	-(2.06)**	-(3.53)***	(0.42)			
Bid-ask Quotes Data	479	59.930	2.599	7.145	-59.384	-2.166	2.615	0.4619	0.4562	81.36***
	(t-value)	(9.00)***	(5.19)***	(0.73)	-(3.62)***	-(3.06)***	(0.03)			

*significant at 10% level.
**significant at 5% level .
***significant at 1% level.

Model:

$$|e_t| = \delta_0 + \delta_1 TTM + \delta_2 Volatility + \delta_3 D + \delta_4 DTTM + \delta_5 DVolatility + \varepsilon_t$$

where

$|e_t|$ is the average absolute pricing error on day t for zero-cost based on respective dataset
TTM is the time to maturity of the contract
Volatility represents the log difference of day high and day low of the spot month futures contract
D is a dummy variable that separates the period before and after the change; where D=0 before shift and D=1 after shift

Table 7
Impact of Time-to-Maturity and Volatility on Dynamic Efficiency of the Markets (based on Zero-Cost)

	N	ϖ_0	ϖ_1	ϖ_2	ϖ_3	ϖ_4	ϖ_5	R^2	Adj R^2	F
Transaction Prices Data	452	2776.952	65.169	-161.116	378.341	32.262	-6450.115	0.0719	0.0615	6.92***
	(t-value)	(9.43)***	(2.84)***	-(0.38)	(0.52)	(1.01)	-(1.83)*			
Bid-ask Quotes Data	479	907.579	47.618	55.095	-524.701	-48.784	-1192.056	0.2478	0.2399	31.24***
	(t-value)	(5.47)***	(3.82)***	(0.23)	-(1.29)	-(2.77)***	-(0.60)			

*significant at 10% level.
**significant at 5% level .
***significant at 1% level.

Model:

$$|\text{Time}| = \varpi_0 + \varpi_1 TTM + \varpi_2 Volatility + \varpi_3 D + \varpi_4 DTTM + \varpi_5 DVolatility + \varepsilon_t$$

where

$|\text{Time}|$ is the average absolute time for the mispricing to disappear on day t for zero-cost based on respective dataset
TTM is the time to maturity of the contract
Volatility represents the log difference of day high and day low of the spot month futures contract
D is a dummy variable that separates the period before and after the change; where D=0 before shift and D=1 after shift

Figure 1. Frequency Distribution of Quoted Spreads: Futures

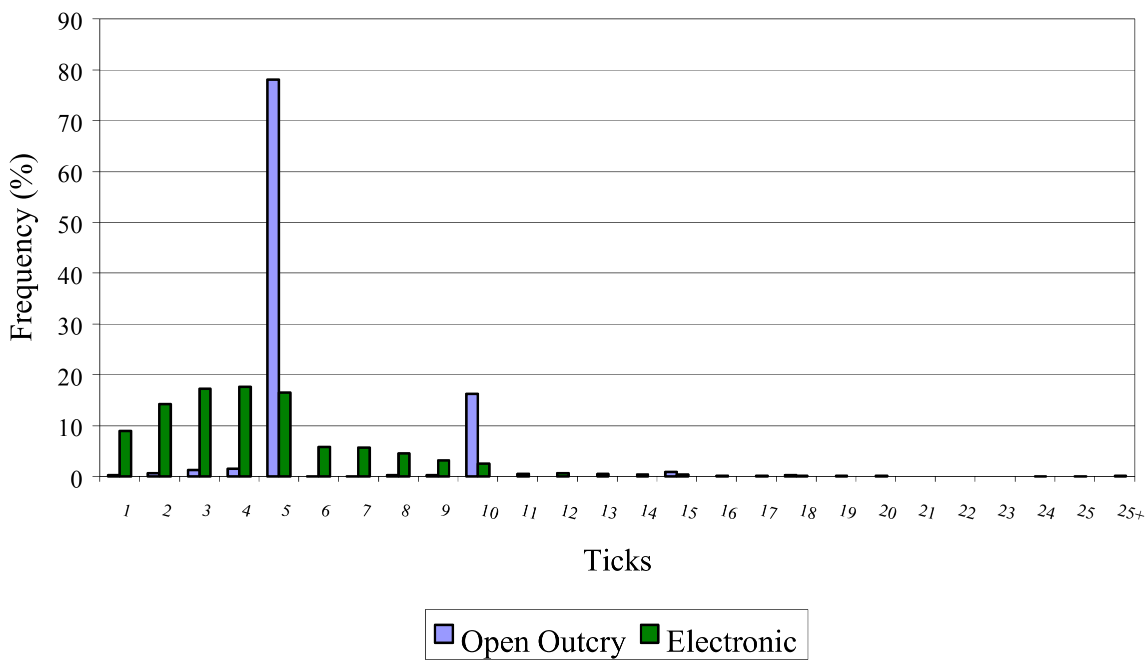

Figure 2. Frequency Distribution of Quoted Spreads: Calls

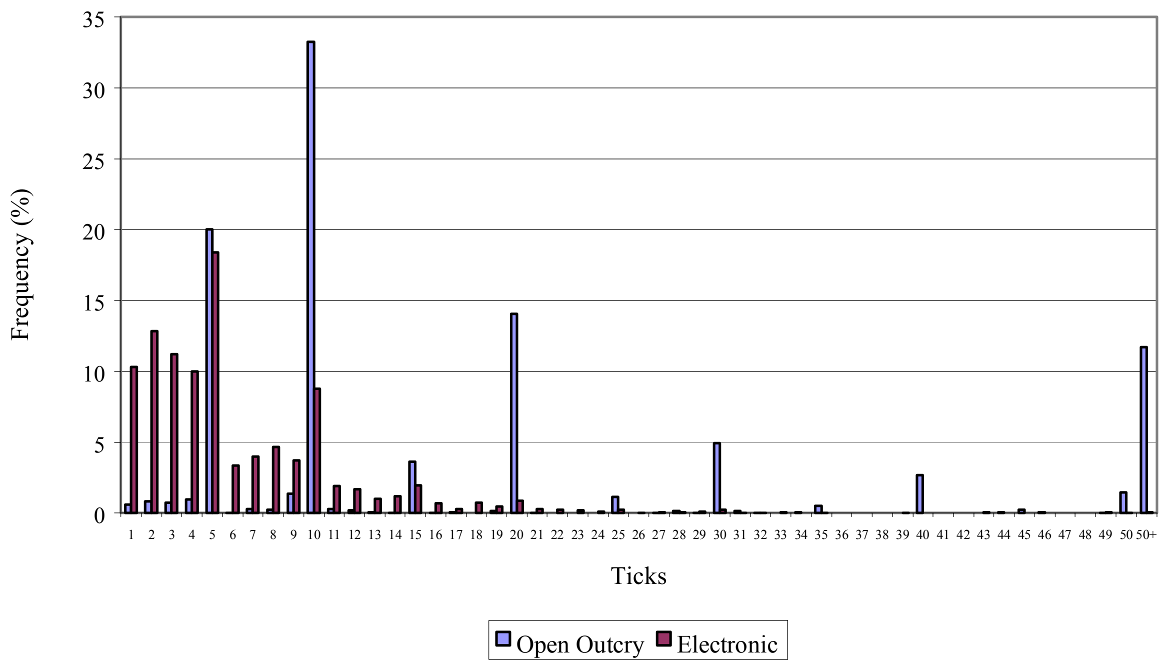

Figure 3. Frequency Distribution of Quoted Spreads: Puts