PRICING DYNAMICS OF INDEX OPTIONS AND INDEX FUTURES IN HONG KONG BEFORE AND DURING THE ASIAN FINANCIAL CRISIS

LOUIS T. W. CHENG*
JOSEPH K. W. FUNG
KAM C. CHAN

This article studies the impact of the Asian financial crisis on index options and index futures markets in Hong Kong. We employed a time-stamped transaction data set of the Hang Seng Index options and futures contracts that were traded on the Hong Kong Futures Exchange. The results show that during the crisis period, the arbitrage profits, and the standard deviations of these profits increased in both ex-post and ex-ante analyses. In a market turbulent time, market vol-

*Correspondence author, Associate Professor of Finance, Department of Business Studies, Hong Kong Polytechnic University, Hung Hom, Hong Kong.
This research project was supported by research grants from the Hong Kong Baptist University and the Hong Kong Polytechnic University. Chan also acknowledges the financial support from a visiting scholar program at Hong Kong Baptist University. We would like to thank the Hong Kong Futures Exchange for providing the data, and acknowledge Castor Pang and Tak Yan Leung for their excellent research assistance.

- *Louis T. W. Cheng is an Associate Professor of Finance in the Department of Business Studies at Hong Kong Polytechnic University in Hong Kong.*
- *Joseph K. W. Fung is an Associate Professor of Finance in the Department of Finance and Decision Sciences in the School of Business at Hong Kong Baptist University in Hong Kong.*
- *Kam C. Chan is an Associate Professor of Finance in the Department of Economics and Finance at the University of Dayton in Dayton, Ohio.*

The Journal of Futures Markets, Vol. 20, No. 2, 145–166 (2000)

atility brings a higher arbitrage profit level. However, despite the increased market volatility, the profitability of the arbitrage trades declined substantially with longer execution time lags in the ex-ante analysis. This suggests that the HSI futures and options markets are mature and resilient. A multiple regression analysis on the ex-post arbitrage profit also suggests that there were structural changes during the Asian financial crisis and the Hong Kong government intervention periods. © 2000 John Wiley & Sons, Inc. Jrl Fut Mark 20: 145–166, 2000

INTRODUCTION

The pricing efficiency of the index options and futures has been of interest among academics and practitioners. During the Asian financial crisis, the financial markets throughout the world, especially in Asia, exhibited tremendous volatility and encountered substantial speculative activity. Derivatives markets such as the Hong Kong Hang Seng Index (HSI) options and futures markets experienced a wide swing in prices and in trading activity. Hence, it would be important to study the potential mispricing of the put-call-futures parity condition under the turbulent time period, during the Asian financial crisis, in a regional financial center such as Hong Kong.

The objective of this article is to reexamine the joint pricing relationship of Hong Kong HSI options and HSI futures markets between January 1996 and August 1998. Unlike previous studies, we use a larger transaction data sample and examine both the ex-post and ex-ante arbitrage profit opportunities from the put-call-futures parity mispricing for the period before and during the Asian financial crisis. In addition, a multiple regression analysis and the Chow test are used to evaluate the impact of the Asian financial crisis on the underlying factors that explain possible arbitrage profits from the index options and futures markets mispricing. The empirical results suggest that, during the Asian financial crisis and the Hong Kong government's intervention, there were dramatic effects on the HSI options and futures pricing behavior.

In essence, the arbitrage profits from the ex-ante and ex-post trading simulations increased substantially. In addition, the underlying factors that explain arbitrage profits experienced a structural shift during the Asian financial crisis as well as the Hong Kong government intervention periods. Nevertheless, based on the ex-ante analysis during the months when the markets were under stress including both the Asian financial crisis and the intervention periods; the pricing dynamics of both index futures and options continued to hold and the possible trading profit with

longer time lapses declined. The declining trading profit suggests that the dynamic pricing relationship between index futures and index options held up well during this turbulent market period.

IMPACTS OF THE ASIAN FINANCIAL CRISIS ON THE HONG KONG FINANCIAL MARKETS

The Crisis

In May 1997, the Thai baht was under a speculative attack. On July 2, the Thai central bank was forced to replace its fixed exchange rate system with a managed-floating one, which meant a de facto devaluation. This marked the beginning of a roller coaster ride for the Hong Kong securities markets. During the period July 1997–February 1998, several major Asian countries including Malaysia, the Philippines, Indonesia, and South Korea suffered substantial currency depreciation. By February 1998, the Indonesian rupiah depreciated over 75%, and the Malaysian ringgit, Philippine peso, Thai baht, and Korean won all lost between 40% to 50% of their pre-crisis values.

With a currency board in operation, the exchange rate of the Hong Kong dollar remained unchanged during the period. However, Hong Kong paid a huge price to maintain its currency value. Following the Thai currency crisis, between 28 August and 1 September 1997, the Hong Kong stock market had three consecutive days of decline (30 August and 31 August were weekends) losing a total of 15% of the Hang Seng Index. In reaction to the mounting pressure for Hong Kong dollar devaluation, the HSI went into a free fall on 20 October 1997 for seven trading days in a row. On 28 October 1997, the HSI fell sharply by 14.7%, ending a week-long collapse which resulted in a total cumulative loss of 40% in the HSI. In January 1998, the Hong Kong stock market again plummeted further: between 5 January and 12 January 1998, the HSI faced six consecutive days of decline and the daily loss varied from 1.6% to 9.1%.

Government Intervention

In early August 1998, unusual short-selling pressure on the Hong Kong dollar, the HSI composite stocks, and the HSI futures were detected. Facing the potential collapse of investor confidence in the pegged currency system and in the securities markets, on 14 August 1998, the Hong Kong government decided to counterbalance the selling pressure in these

markets. Specifically, the Hong Kong government: (i) bought a substantial amount of Hong Kong dollars with U.S. dollars (about US$5.5 billion on August 14, 1998) through the Hong Kong Foreign Exchange Reserve Fund; (ii) took a long position for all the 33 HSI composite stocks in order to maintain the HSI at around the 7,800 level; and (iii) bought a large quantity of HSI futures contracts (about 40,000 contracts). By 29 August 1998, the Hong Kong government successfully defended the HSI at the 7,800 level. But the cost involved was enormous—a staggering US$15.4 billion had been invested.

HYPOTHESIS AND MODELS

When the stock market is in turmoil, the derivatives markets will also be affected. As the volatility of the stock market and the volume of the derivatives trading increase, greater mispricing for the index options and futures arbitrage is possible. In addition, when the market is under stress (that is, demonstrated by extremely large upward or downward movements), investor behavior may become irrational and larger pricing errors may occur more frequently and persistently.

Consequently, we hypothesize that the greater mispricing during the crisis was mainly due to the low liquidity in the options pit, which resulted in a lagged adjustment of the options price (relative to the faster adjustment in the futures price) during rapid market condition changes. An increase in volume and liquidity under normal market conditions can improve the efficiency of the market. However, the heightened volatility during the crisis period could widen the gap between the actual and fair values of securities, because an increase in volatility in the futures and options pits increases the execution risk for arbitrageurs, greater mispricing can occur in the market for a longer time period.

For a truly mature and resilient market, it should be possible to resume pricing efficiency quickly under stressful conditions. As an index options and futures arbitrage requires simultaneous trading between the two derivatives markets, it helps reveal the pricing errors between index options and futures, which in turn depend on the cash market. In order to maintain a jointly efficient options and futures markets, the investors have to synchronize the price movements in the two derivatives and the cash markets. Consequently, index options and futures arbitrage serves as an ultimate joint test (that is, a higher order test) of pricing efficiencies of index futures and index options markets.

The objective of this study is to evaluate how well the derivatives markets in Hong Kong can maintain their joint pricing efficiency during

extreme market conditions such as the recent Asian financial crisis. We compare the profits of HSI index options and futures arbitrages before the crisis, during the crisis, and during the Hong Kong government intervention period. This comparison will shed some light on the maturity of the relatively new index futures and options markets in Hong Kong.

Put-Call-Futures Parity Condition

The price of a stock index futures contract is related to its underlying cash index through the cost-of-carry model (Cornell & French, 1983; Modest & Sundaresan, 1983). On the other hand, the prices of index options contracts are linked to their underlying index via the put-call-parity condition (Stoll, 1969). Thus, a direct relationship exists between options and futures contracts that share the same underlying asset. When all contracts share a common expiration date and the options are of European-style, buying a call and writing a put will generate a riskless cash flow that equals the difference between the futures price and the exercise price of the options. Consequently, the cost of the options portfolio (that is, call price minus put price) must be equal to the present value of the difference between the futures price and the common exercise price of the options. This parity relationship is well explained by Tucker (1991) and Lee and Nayar (1993):

$$C_0 - P_0 = (F_0 - X)\left(1 + \frac{r}{365}\right)^{-(t_1 - t_0)} \qquad (1)$$

where C_0, P_0, and F_0 are synchronous prices at the current date t_0 of the call and put options, and of the futures contract, respectively. All three contracts expire at the same future date t_1. X is the common exercise price for the options and $(t_1 - t_0)$ is the time-to-maturity or the holding period for all three contracts where t_1 and t_0 are in fractions of a year. Finally, r stands for the risk-free rate for the period.

Rearranging eq. (1), the parity value of the futures contract F_0^* can be written as:

$$F_0^* = X + (C_0 - P_0)\left(1 + \frac{r}{365}\right)^{-t_1 - t_0} \qquad (2)$$

If the actual futures price (F_0) is above F_0^*, then the investor can short the (overpriced) futures contract at F_0, buy the call at C_0, and short the put at P_0. If the call is more expensive than the put, the investor should borrow the difference to finance the options portfolio. If the call is

cheaper than the put, then the investor should invest the proceeds in the risk-free asset for the holding period. The above process is defined as a short-futures arbitrage, hereafter. On the other hand, if the futures price (F_0) is below F_0^*, then the investor should buy the (underpriced) futures, short the call and buy the put. If the call price is higher than the put price, then the investor should invest the proceeds in a risk-free asset. If the opposite is true, then the investor should borrow at risk-free rate and finance the options portfolio. This process is defined as a long-futures arbitrage, hereafter. Finally, both strategies will yield a cash flow of $|F_0 - F_0^*|$ at the common expiration date of the contracts.

This parity condition is widely used in practice, and market-makers in options markets commonly use futures contracts to hedge their positions. For example, Fleming, Ostdiek, and Whaley (1996) show that dealers price the S&P 100 index options with the prevailing S&P 500 futures price. Fung et al. (1997) and Fung and Fung (1997) employ the parity condition to study the joint pricing efficiency of the HSI options and futures contracts and suggest that trading strategies, based on possible mispricing on the put-call-futures parity condition, do not yield profits that are more than the trading cost. Cheng et al. (1998) further examine the potential added value of the early unwinding strategy on the HSI options and futures arbitrage. They find that early unwinding can help improve arbitrage profit, but only for ex-ante trades that are executed within five minutes. However, the empirical studies on the mispricing of put-call-futures parity are based on transaction data in normal market conditions before 1997. In this study, we employ the most recent data from January 1996 till August 1998, which include both upward and stable as well as downward and volatile financial markets in Hong Kong.

TRADING COSTS, DATA, AND METHODOLOGY

Trading Costs

A profitable arbitrage for the hold-to-expiration strategy requires the pricing error to be larger than the total round-trip cost incurred in the arbitrage process. Previous studies such as Lee and Nayar (1993) and Fung and Fung (1997) considered various cost items in their studies.[1] The cost

[1]Lee and Nayar (1993) have factored in the bid–ask spread for market-impact cost; and Fung and Fung (1997) have accounted for differential interest rates and the opportunity cost of margin deposits. Upon approval by the Hong Kong Futures Exchange, members may use interest-bearing instruments for margin deposits.

of the arbitrage includes the interest spread between the lending and borrowing rates; the trading costs; the opportunity cost of margin deposits; and the market-impact costs. In our analysis, we examine the arbitrage profits from the perspectives of two different cost structures: member and non-member investors. Member investors are members of the Hong Kong Futures Exchange (HKFE). These investors do not need to pay commission fees nor financing costs (as they can use interest-bearing securities as margin deposits and so they incur no opportunity cost for their investment). Members only pay the exchange-related fees. For the non-members, they are regular investors who have to pay all the components of the transaction cost.

The HKFE charges member firms various trading fees per contract per trade. The Exchange charges a one-way trading fee per trade for the futures or options contract; a settlement fee per futures position which is not being closed out before expiration, and an exercise fee on each expired in-the-money option. No charges are levied on expired out-of-money options. Both the exercise fee per options contract and the settlement fee per futures position are set at HK$10 but the trading fees for the options and futures varied over time. Over the sample period, the one-way trading fee was HK$11.50 per trade for each futures and options contract. Therefore, the total exchange charge on members per arbitrage trade for the hold-to-expiration strategy includes one one-way trading fee, one settlement fee for the futures contract, two one-way trading fees and one exercise fee for the options portfolio. With an index multiplier of 50 (that is, HK$50 per index point), the exchange-related trading cost averages around 1.11 index points over the sample period.

Non-members have to pay a trading commission to compensate the member firms for the exchange charges. Being set by the exchange, the minimum one-way commissions for futures and options contracts are HK$100 and HK$60, respectively, for both overnight and day trades.[2] Each arbitrage trade involves one round-trip commission for the futures position and three one-way commissions for the options portfolio.[3] The commission cost to non-members is estimated to be 11.11 index points for the period.

The final component of the transaction cost is the financing cost. For exchange members, we assume that they do not incur any financing costs as they are allowed to use interest-bearing securities as margin de-

[2]Because the settlement day is scheduled on the next business day after the last trading day of the spot month contracts, the day trade commission is irrelevant to the hold-to-expiration strategy.
[3]Another one-way commission is for the in-the-money options but no commission is charged on the expired out-of-the-money options.

posit for the derivatives contracts. However, for the non-members, we assume that they are required to pay cash for the margin deposit, thus resulting in an opportunity cost of financing. The financing cost is a function of the daily Hong Kong Interbank Offer Rate (HIBOR), the number of days before expiration and the margin requirement in index points. Thus the estimated financing cost would vary depending on the combined effect of the market interest rate, the length of time before expiration and the total margin deposit required by that specific arbitrage position.

Data

The HSI options are European-style options. The options and futures contracts share the HSI as their common underlying asset. They also have a common expiration date and follow the same expiration cycle. The high frequency data that we employ permits a matching of the options and futures prices within a one-minute interval for all three contracts (that is, index put, index call, and index futures) required in each simulated put-call-futures arbitrage. This helps to alleviate the nonsynchronous price problem in the analysis. This article only examines the spot month contracts, because they are liquid enough to provide sufficient data for our study. The one-month HIBOR retrieved from DataStream was used as the risk-free interest rate (r). Minute-by-minute quotes of the HSI for the period were obtained from the Hang Seng Index Services Limited.

Time-stamped transaction data of the HSI options and futures contracts were obtained from the HKFE for the period 1 January 1996 to 31 August 1998. This period covers three distinctive time zones: the pre-crisis period, the crisis period, and the government intervention period. The Asian financial crisis was triggered by Thailand's announcement of floating the Baht and its request for the International Monetary Fund's "technical assistance" on 2 July 1997, so we divided our sample at 1 July 1997 for the purpose of classifying the crisis period. From January 1996 to June 1997, we identified 5885 trios (3-way trades) with a minimum arbitrage profit exceeding the transaction cost under the ex-post analysis, and 4137 profitable trios under the ex-ante analysis for the member subsample. For the non-member subsample, 1424 ex-post trades and 879 ex-ante trades were identified.[4]

[4]Cheng, Fung, and Pang (1998), included all trades (that is, zero financing cost or the so-called nonprofitable trades) in their analysis. In both our article and that of Cheng et al., the same procedure was used in defining institutional and individual investors. The results for both ex-post and ex-ante analyses across all three subsamples (that is, zero cost, institutional and individual investors subsamples) demonstrate similar pattern in arbitrage profits throughout their tables. Thus there is no reason to believe that excluding the unprofitable trades would bias our results.

In order to make sure that our study of the mispricing (arbitrage profits) during the Asian financial crisis period is robust, we employed two different classification schemes. First, based on major economic events (such as the Thai baht devaluation) that had an impact on Hong Kong markets as reported in the newspapers, we identified the period from 1 July 1997 to 28 February 1998 as the crisis period (for the purpose of our analysis only). This classification criterion resulted in four monthly subsamples (August 1997, October 1997, January 1998, and February 1998) and a total of 556 trades for the ex-post analysis and 328 trades for the ex-ante analysis for the member subsample. For the non-member subsample, this criterion results in 300 ex-post trades and 174 ex-ante trades.

Secondly, we looked at the daily HSI changes during the period and selected the days which had HSI movements large enough to be included in the crisis subsample. Because, during this period, not all the days were affected by the crisis, we included arbitrage trades that were conducted around the turmoil—this is a purely data-driven procedure. Under this criterion, we first redefine the crisis period by including July 1997 through July 1998 (right before the Hong Kong government intervention in August 1998). This definition does not depend on major economic news related to the Asian financial crisis but focuses on the magnitude of the HSI changes. For the July 1997–July 1998 period, we selected all 3-way trades that occurred during the days when the HSI changes were at least 2% (that is, the HSI went up or down by 2% or more). This classification criterion provides a total of 1,808 ex-post trades and 1,265 ex-ante trades for the member subsample and 733 ex-post trades and 446 ex-ante trades for the non-member subsample. Finally, following the Hong Kong government's announcement of its official intervention in the markets between 14 August and 28 August 1998, we identified 310 ex-post trades and 218 ex-ante trades for the member subsample and 116 ex-post trades and 67 ex-ante trades for non-members during the intervention period.

Methodology

Ex-post and Ex-ante Trading Tests

Call and put options of the same exercise price traded on the same day were matched into a simulated trade when the trading time fell within a 1-minute window. Then we searched for any futures prices, which also

fell within that window. This limits the maximum time lag to 1 minute for all three trades within the simulated arbitrage transaction.

The study adopts both ex-post and ex-ante simulations to compare the feasibility and potential profitability of the hold-to-expiration strategies. Under the ex-post analysis, it is assumed that an arbitrage position is established with the detected mispriced observations.

The ex-post test may be biased by the problem that trades can only be executed at the next set of prices at best. The futures contracts are traded on a system of open-outcry. The futures market is highly liquid and trades can be executed within seconds. However, the options market that is located right next to the futures pit trades with a market-making system. Some time lapse may be required for the floor trader to complete a trade. Following Klemkosky and Lee (1991), a number of time lags are employed in the ex-ante tests. The lags used are between 5 and 30 minutes. Specifically, we set the time lapse intervals as: $0 < \text{lag} \leq 5$ minutes, $5 < \text{lag} \leq 10$ minutes, $10 < \text{lag} \leq 15$ minutes, $15 < \text{lag} \leq 30$ minutes, and 30 minutes<lag. The shorter time lapse is used to account for the possible execution delay and the longer time lapse helps to examine the dynamic efficiency of the markets.

Multiple Regression Analysis

In efficient markets, profitable arbitrage opportunities may simply reflect the inherent difficulties and risks of the process (Kawaller, 1987). For example, execution risk is positively related to market volatility and the risk is higher if illiquid contracts are involved. We modify the model by Fung and Fung (1997) by adding two variables, namely futures volume (FVOL) and options volume (OVOL). The following multiple regression model is adopted to analyze the ex-post data:

$$\pi = \beta_0 + \beta_1\sigma + \beta_2 t + \beta_3 M + \beta_4 \text{FVOL} + \beta_5 \text{OVOL} + \beta_6 S + \varepsilon \quad (3)$$

Where π is the ex-post arbitrage profit for an arbitrage portfolio; σ is the intraday standard deviation of 5-minute returns of the Hang Seng Index futures contract; t is the length of the holding period in a fraction of a year (that is, t_1–t_0); M is a measure of the moneyness with M = |Futures Price − Strike Price/Strike Price|; *FVOL* and *OVOL* are the trading volumes for futures and options contracts, respectively; S is a dummy variable with a value of 1 if it is a long futures arbitrage and zero if it is a short futures arbitrage, and ε is a random error term.

Certain relationships between the magnitude of the ex-post arbitrage profit and the independent variables are expected. β_1 is expected to be positive. σ is the intraday standard deviation of the changes of the futures prices. It measures the price risk in establishing a futures position and proxies the volatility of the market in general. Volatile markets increase the executive risk in establishing all legs of the arbitrage portfolio. Hence, arbitrageurs require a bigger mispricing or margin of safety during a volatile market before initiating an arbitrage trade. Therefore, the mispricing is expected to be higher in a volatile market.

The variable t is the time to expiration of the arbitrage portfolio. The longer the time-to-expiration, the higher the value of the early-unwinding options in the arbitrage portfolio (Brennan & Schwartz, 1990), and arbitrageurs require a smaller mispricing before initiating an arbitrage trade. On the other hand, the mispricing converges to zero as both the futures and options contracts converge to the settlement value. The shorter the time-to-expiration, the smaller the mispricing is. Hence the sign of β_2 depends on the balance of the two forces.

The variable M denotes the difference between the current futures price and the exercise price of the option used in the arbitrage portfolio. Futures traders widely use options to hedge their futures positions. The cheapest option to use is the one with an exercise price closest to the current futures price. Options with an exercise price close to the current futures price should have greater liquidity and smaller mispricing. Therefore, the sign of β_3 should be positive.

The increase in the trading volume for futures raises the demand for options position for hedging and arbitrage. Whereas other things remain unchanged, the excess demand for options position distorts the price of options and thus widens the magnitude of mispricing. However, if there is an increase in the trading volume for options to accommodate the excess demand for options positions, the degree of price distortion and mispricing should be less. In addition, it should be noted that increases in futures and options volumes are associated with greater market volatility. When all these factors mix together, the signs of β_4 and β_5 are uncertain. The sign of β_6 is uncertain as we do not have the information to know whether a long or a short futures strategy brings higher arbitrage profit.

To examine a possible structural change of the relationship between arbitrage profits and other variables during the Asian financial crisis, we conducted a Chow test on eq. (3). We hypothesize that, during the Asian financial crisis, the structural relationship exhibited in eq. (3) would be different as there were abnormal trading activities during those months.

Therefore, we expected the Chow test to be statistically significant. For the Hong Kong government intervention period, we conducted the Chow test in a similar manner.

EMPIRICAL RESULTS

Ex-Post Tests

Table I Panel (A) presents the ex-post arbitrage profits for the sample of months before the Asian financial crisis from January 1996 to June 1997. All the arbitrage profits in both long and short futures strategies are significantly different from zero at the 1% level. Because we have factored in the relevant costs of arbitrage, which includes trading and opportunity cost of margin deposits, the arbitrage profit is pure profit. Therefore, the profit figures are indeed economically significant. The arbitrage profits for members and non-members are 12.39 and 17.77 index points respectively for all ex-post trades. The seemingly higher profit for non-members is due to the fact that non-members are subject to higher trading costs, leading to a smaller but more profitable subsample of trades being used to construct their mean arbitrage profit.

The long-futures strategy and short-futures strategy produce very similar profit (12.66 and 12.13 index points, respectively) for members but slightly different profits (19.77 and 15.89 index points respectively) for non-members. Overall speaking, the profit level for both strategies in both subsamples indicate that there are only minimal opportunities to make arbitrage profit (US$75 to US$125 per 3-way trade) in the HSI options and futures markets before the Asian financial crisis. Ex-post results for the months during the Asian financial crisis are in Table I Panels (B) and (C). Panel (B) of Table I defines the crisis period as the months of August and October in 1997; and of January and February in 1998. In Panel (B), the mean arbitrage profits during the Asian financial crisis for both members and non-members are 28.18 and 27.42 points respectively. The long and short strategies for both subsamples show almost identical profits as well.

Panel (C) of Table I defines the crisis as days during the period from July 1997 and July 1998 with a 2% or greater changes in the HSI. This second method of defining crisis results in an ex-post profit of 31.16 points for members and 40.40 points for non-members. Once again, within each subsample, both strategies show very similar profits. Comparing Panel (A) with Panels (B) and (C), we observe that all the mean

TABLE I

Arbitrage Profits in Hong Kong Hang Seng Index Futures and Options Markets: An Ex-post Analysis

	Member			Non-Member		
	N	*Mean* *t-value* *S.D.*	*Max* *Med* *Min*	*N*	*Mean* *t-value* *S.D.*	*Max* *Med* *Min*
Panel (A): Before the Asian Financial Crisis (January 1996 to June 1997)						
All Ex-post Trades	5885	12.39	379.10	1424	17.77	368.44
		47.58**	7.95		20.63**	6.55
		19.97	0.00		32.50	0.03
Long-futures Strategy	2893	12.66	379.10	688	19.77	368.44
		30.13**	7.85		13.54**	6.97
		22.60	0.00		38.29	0.03
Short-futures Strategy	2992	12.13	214.8	736	15.89	196.49
		38.89**	8.21		16.69**	6.32
		17.05	0.00		25.83	0.03
Panel (B): During Asian Financial Crisis (August 1997, October 1997, January 1998, and February 1998)						
All Ex-post Trades	556	28.18	295.28	300	27.42	255.84
		19.81**	18.78		13.28**	17.29
		33.54	0.02		35.76	0.15
Long-futures Strategy	322	28.84	287.36	184	27.01	250.55
		15.21**	18.94		10.11**	16.84
		34.02	0.22		36.25	0.43
Short-futures Strategy	234	27.28	295.29	116	28.06	255.84
		12.68**	16.95		8.61**	19.02
		32.92	0.03		35.11	0.15
Panel (C): During the Asian Financial Crisis (Days with +/− 2% changes in Hang Seng Index from July 1997 to July 1998)						
All Ex-post Trades	1808	31.16	388.77	733	40.40	368.72
		25.64**	16.86		15.85**	14.92
		51.67	0.00		69.01	0.01
Long-futures Strategy	962	31.32	388.77	390	41.51	368.72
		17.99**	16.73		11.29**	14.74
		53.99	0.15		72.62	0.01
Short-futures Strategy	846	30.98	368.91	343	39.15	339.76
		18.42**	17.30		11.20**	15.27
		48.92	0.00		64.75	0.13
Panel (D): During the Hong Kong Government Intervention (14 to 28 1998)						
All Ex-post Trades	310	32.48	398.91	116	51.30	381.69
		9.11**	15.24		6.07**	11.99
		62.76	0.15		91.06	0.17
Long-futures Strategy	176	28.36	349.90	66	42.46	331.57
		6.54**	14.93		4.02**	7.75
		57.55	0.29		85.62	0.17
Short-futures Strategy	134	37.90	398.91	50	62.97	381.69
		6.37**	17.91		4.57**	20.78
		68.86	0.15		97.42	0.17

**1% significant; *5% significant.

arbitrage profits in Panels (B) and (C) are substantially higher than the corresponding mean arbitrage profits in Panel (A). On the other hand, except for the long-futures strategy in the non-member category, the standard deviations of the arbitrage profits in Panels (B) and (C) are larger than those in Panel (A). These findings of increasing standard deviation in the HSI options and futures markets, suggest that, during the Asian financial crisis, the increased volatility of the cash index led to higher ex-post arbitrage profits and risk.[5]

The arbitrage profit for the Hong Kong government intervention period in August of 1998 are in Table I Panel (D). Except the average profit level for the long-futures strategy in the member category, all other remaining categories yield the highest average profit levels among all four Panels from (A) to (D). In addition, the standard deviations of all six categories for both members and non-members are also the largest when compared with their corresponding figures in the other Panels of Table I. These results indicate that, during the Hong Kong government intervention, there were extraordinary trading activities in the index futures and options markets. Accordingly, the explosive trading activities resulted in the highest average arbitrage trading profit as well as the highest risk in arbitrage activities.

One important observation in Panel (D) is that the profits for the short strategy are significantly higher than those for the long strategy for both members (37.9 points vs 28.36 points) and non-members (62.97 points vs. 42.46 points). The reason for such a change (relative to the other Panels) is that the government bought a huge number of HSI futures contracts during the intervention period, causing the price of HSI futures to rise. Consequently, the average size of underpricing of the futures contracts was reduced substantially (that is, the long-future arbitrage profit) relative to the average size of overpricing of the futures contracts (that is, the short-futures arbitrage profit).

Ex-Ante Tests

Table II presents the ex-ante analysis of the arbitrage profit of the HSI Index futures and options markets. All the Panels have the same order of

[5]Higher volatility can lead to greater measurement error because volatility aggravates the non-synchronous price problem in the matching criterion. That is why we adopted the 1-minute maximum time gap criterion for the put-call-futures simulated trades in order to minimize the problems of measurement errors created by time difference. The 1-minute criterion is the most restricted procedure used in the literature. Additional research indicates that the average time between arbitrage trades in our sample is about 36 minutes. Therefore a maximum of 1-minute gap should not result in a measurement error having the magnitude similar to our arbitrage profit during the crisis period.

TABLE II

Arbitrage Profits on Hong Kong Hang Seng Index Futures and Options Markets: An Ex-ante Analysis

	Member			*Non-Member*		
	N	*Mean* *t-value* *S.D.*	*Max* *Med* *Min*	*N*	*Mean* *t-value* *S.D.*	*Max* *Med* *Min*
Panel (A): Before the Asian Financial Crisis (January 1996 to June 1997)						
All Ex-ante Trades	4137	2.30 9.72** 15.26	90.91 2.94 −93.09	879	−7.75 −12.47** 18.43	80.02 −8.40 −82.81
0 min < Lag ≤ 5 mins	1603	5.20 12.39** 16.79	90.91 4.90 −93.09	323	−0.34 −0.31 19.65	80.02 −1.33 −81.90
5 mins < Lag ≤ 10 mins	410	1.54 2.22** 14.06	90.01 1.81 −66.09	87	−8.82 −4.88** 16.86	48.33 −7.89 −82.81
10 mins < Lag ≤ 15 mins	319	−0.67 −0.94 12.74	38.28 0.27 −84.09	61	−15.44 −8.45** 14.27	16.12 −14.59 −48.07
15 mins < Lag ≤ 30 mins	554	−0.22 −0.41 12.67	80.91 −1.04 −48.84	114	−13.09 −10.31** 13.56	65.29 −13.78 −43.52
30 mins < Lag	1251	0.72 1.75 14.61	99.96 −0.03 −76.09	294	−11.92 −11.88** 17.20	78.02 −13.15 −68.42
Panel (B): During the Asian Financial Crisis (August 1997, October 1997, January 1998, and February 1998)						
All Ex-ante Trades	328	9.52 5.67** 30.42	88.94 7.90 −92.18	174	−1.72 −0.68 33.26	76.07 −2.44 −108.28
0 min < Lag ≤ 5 mins	110	21.93 7.51** 30.62	88.94 15.80 −60.80	67	14.38 3.73** 31.60	76.07 16.35 −78.14
5 mins < Lag ≤ 10 mins	22	2.88 0.43 31.21	72.62 1.35 −56.09	9	9.09 1.10 24.89	56.11 11.37 −16.35
10 mins < Lag ≤ 15 mins	13	7.50 1.03 26.28	44.03 13.79 −40.89	6	−18.67 −1.53 29.86	5.90 −3.52 −56.99
15 mins < Lag ≤ 30 mins	52	4.02 0.93 31.16	83.91 4.12 −92.18	30	−14.64 −2.25* 35.68	71.04 −17.68 −108.28
30 mins < Lag	131	2.60 1.09 27.23	88.91 3.87 −90.33	62	−12.80 −3.66** 27.56	45.42 −14.83 −108.20

TABLE II (Continued)

Arbitrage Profits on Hong Kong Hang Seng Index Futures and Options Markets: An Ex-ante Analysis

	Member			*Non-Member*		
	N	*Mean* *t-value* *S.D.*	*Max* *Med* *Min*	*N*	*Mean* *t-value* *S.D.*	*Max* *Med* *Min*
Panel (A): Before the Asian Financial Crisis (January 1996 to June 1997)						
All Ex-ante Trades	1265	7.65	93.29	446	−4.32	73.25
		10.94**	8.57		−3.26**	−3.37
		24.87	−76.48		27.93	−92.12
0 min < Lag ≤ 5 mins	511	14.33	93.29	188	5.78	73.25
		12.89**	12.74		2.99**	5.64
		23.33	−76.48		26.49	−71.52
5 mins < Lag ≤ 10 mins	123	2.42	92.74	43	−10.54	72.69
		1.00	−0.73		−2.01*	−9.27
		21.95	−71.09		34.47	−87.19
10 mins < Lag ≤ 15 mins	88	7.28	73.80	32	−5.26	37.63
		2.87**	7.80		−1.17	−5.87
		23.82	−47.59		25.35	−64.10
15 mins < Lag ≤ 30 mins	173	0.99	62.19	64	−10.95	39.78
		0.60	1.96		−3.90**	−11.74
		21.68	−76.23		22.43	−72.96
30 mins < Lag	370	3.38	89.99	119	−14.19	61.31
		2.52**	3.68		−5.90***	−12.70
		25.75	−76.06		25.90	−92.13
Panel (D): During the Hong Kong Government Intervention 14 to 28 (1998)						
All Ex-ante Trades	218	5.15	88.91	67	−8.68	60.98
		3.23**	4.86		−2.45*	−7.67
		23.55	−69.78		28.98	−89.78
0 min < Lag ≤ 5 mins	94	8.84	88.91	31	−6.19	60.97
		3.35**	8.89		−0.98	1.74
		25.57	−69.78		35.13	−89.78
5 mins < Lag ≤ 10 mins	23	−0.94	33.57	6	−12.57	8.43
		−0.24	−1.17		−1.28	−7.81
		18.65	−41.09		24.57	−58.30
10 mins < Lag ≤ 15 mins	11	−2.21	48.36	2	−32.40	−19.56
		−0.31	−4.86		−2.52*	−32.41
		23.38	−25.87		18.17	−45.26
15 mins < Lag ≤ 30 mins	28	7.00	77.55	9	−1.14	57.55
		1.63	6.99		−0.12	−11.44
		22.65	−36.04		27.76	−33.09
30 mins < Lag	62	2.29	59.30	19	−12.58	35.63
		0.87	2.54		−2.83**	−14.86
		21.87	−60.26		19.40	61.23

**1% significance level.
*5% significance level.

presentation as Table I. The most profitable trades occur when the lapse time is between 0 and 5 minutes in all four Panels (except for the non-member category in Panel (D)). All the time intervals for non-member category in Panels (A) and (D) yield negative average profit. During the Asian financial crisis in Panels (B) and (C), the average arbitrage profits for both members and non-members for all ex-ante trades in the (0 minute $<$ lag $\leq$ 5 minutes) subsamples are higher than those corresponding mean arbitrage profits in Panel (A). During the Asian financial crisis months, for the (0 minute $<$ lag $\leq$ 5 minutes) interval, the mean profit for members increased to 21.93 points in Panel (B) (compared with the 5.20 points before the crisis in Panel (A)).

For non-members, the mean profit for the (0 minute $<$ lag $\leq$ 5 minutes) interval is 14.38 points during the Asian financial crisis in Panel (B) in sharp contrast to only –0.34 points before the Asian financial crisis sample in Panel (A). In addition, with regards to the standard deviations of the ex-ante trading profit, all time intervals in Panel (B) exhibit larger standard deviations than those in the corresponding intervals in Panel (A). When we compare Panel (A) with Panel (C), the conclusion is the same.

Whereas Panel (D) (that is, the government intervention period) has slightly higher average profit than Panel (A), Panel (D) has substantial higher standard deviation levels. However, unlike the results from Table I, Panel (D) no longer shows the largest average arbitrage profits among all Panels. In short, during the Asian financial crisis and the intervention periods, there were larger arbitrage profits as well as higher risk in the HSI futures and options markets.

Multiple Regression Analysis

Table III presents the multiple regression analysis for the arbitrage profit under the hold-to-expiration strategy. Panels (A) and (B) report the results for members and non-members respectively. Under the member subsample, the magnitude of the profit is positively related to market volatility, time-to-maturity of the contract, moneyness of the options, and the trading volume of the futures contract. On the other hand, an increase in the trading volumes for index options, an increase in the average return on futures trading, and a short futures strategy tend to reduce the size of the profit.

Intraday volatility and futures volume are persistently significant in the regressions whereas options volume is not, indicating that the level of arbitrage profit is dominated by the futures contracts. This result is

TABLE III

Determinants of Ex-post Arbitrage Profit and the Chow Tests from January 1996 to February 1998

Panel (A): Members

	Dependent Variable: Arbitrage Profit		
Independent Variables	*Full Sample (Jan 96 to Feb 98)*	*Before the Crisis (Jan 96 to June 97)*	*During the Crisis (July 97 to Feb 98)*
Constant	−1.29	1.62	2.26
	(−1.24)	(1.44)	(0.44)
Intraday std dev. of futures prices (σ)	7592.06	2602.51	8194.26
	(10.95)**	(2.46)*	(54.9)**
Time to maturity (T)	0.21	0.18	0.26
	(6.22)**	(5.51)**	(1.55)
Moneyness (M)	1.77	0.94	3.69
	(4.52)**	(2.26)*	(1.24)
Futures volume (FVOL)	0.62E-03	0.45E-03	0.64E-03
	(10.38)**	(6.43)**	(3.34)**
Options volume (OVOL)	−0.19E-2	−0.74E-03	−0.29E-02
	(−7.95)**	(−2.87)**	(−3.22)**
Strategy (S = 0 for Long futures;	−0.52	−0.61	−0.80
S = 1 for short futures)	(−0.97)	(−1.18)	(−0.30)
Adj. R^2	0.0998	0.0199	0.1848
F	113.93**	19.76**	22.61**
Number of Observations	6441	5885	556
Chow test F-statistics = 2215.22**			
Panel (B): Non-Members			
Constant	6.79	9.82	1.63
	(2.24)*	(2.54)**	(0.22)
Intraday std dev. of futures prices (σ)	7320.43	2342.41	7229.60
	(4.90)**	(0.70)	(3.95)**
Time to maturity (T)	0.53	0.52	0.31
	(5.04)**	(4.46)**	(1.21)
Moneyness (M)	1.01	−1.15	4.81
	(0.96)	(−0.86)	(2.77)**
Futures volume (FVOL)	0.45E-03	0.24E-03	0.68E-03
	(2.90)**	(0.99)	(2.66)**
Options volume (OVOL)	−0.27E-02	−0.86E-04	−0.12E-2
	(−4.07)**	(−0.95)	(−3.28)**
Strategy (S = 0 for long futures;	−3.42	−4.25	0.74
S = 1 for short futures)	(−2.01)*	(−2.24)*	(0.18)
Adj R^2	0.0669	0.0171	0.2012
F	19.51**	4.59**	13.93**
Number of Observations	1724	1424	300
Chow test F-statistics = 69.19**			

t-statistics are in parentheses.
**1% significance level.
*5% significance level.

logical because the HSI futures market is much larger than the options market. Consequently the futures volatility and futures volume should have a stronger effect on arbitrage profit than the options volume.

This hypothesis is based on the argument that the mispricing is mainly due to the low liquidity in the options which results in a lagged adjustment of the options price (relative to the rapid adjustment in the futures price) during rapid market condition changes. Because an increase in volatility in the futures and options pits increases the execution risk for arbitrageurs, greater mispricing will be induced in the market for a longer time period.

Appendix A illustrates our argument mentioned above. Comparing the trading volume before and during the crisis period, we find that the futures volume has increased a lot more than the options volume. On the other hand, during the intervention period, both the options and futures volumes increased by a similar percentage. However, as the futures volume is much larger than the options volume, the futures volume will result in a much faster price adjustment than the options. Consequently, the number and magnitude of mispricing for the arbitrage trades would be greater as well. In addition, the volatility has also increased significantly during the crisis and the intervention periods. This result supports the argument that volume is positively correlated with mispricing.

The results for non-members are mostly consistent with the above findings. We note that, during the Asian financial crisis, the magnitudes of the regression coefficients are larger than the corresponding coefficients before the crisis. The Chow test statistics are rejected at the 1% level, which suggests that there were structural changes in eq. (3) during the Asian financial crisis.

Table IV repeats the same regression analysis for the government intervention period. The results are basically the same as those in Table III. The F statistic from the Chow test also shows that there exists a statistically significant structural shift between the pre-crisis and the intervention periods. One important change during the intervention period is that all the regression variables become insignificant for both member and non-member subsamples. The results from Tables III and IV suggest that the government intervention activities altered the price dynamics and relationships among the regression variables and arbitrage profits in the HSI futures and options markets. Due to the intervention, an unexpected supply of futures contracts was created by the government, leading to distorted and random pricing movements in the markets.

TABLE IV

Determinants of Ex-post Arbitrage Profit and the Chow Tests from January 1996 to June 1997 and Hong Kong Government Intervention Period in August 1998

Panel (A): Members

	Dependent Variable: Arbitrage Profit		
Independent Variables	*Full Sample (Jan 96 to June 97 and Aug 14–28, 98)*	*Before the Crisis (Jan 96 to June 97)*	*During the Intervention (Aug 14–28, 98)*
Constant	1.15	1.62	−18.79
	(1.00)	(1.44)	(−0.34)
Intraday std dev. of futures prices (σ)	1907.37	2602.51	950.92
	(2.01)*	(2.46)*	(0.16)
Time to maturity (T)	0.15	0.18	−0.68
	(3.85)**	(5.51)**	(−0.56)
Moneyness (M)	2.03	0.94	7.46
	(4.41)**	(2.26)*	(0.96)
Futures volume (FVOL)	0.44E-03	0.45E-03	0.54E-04
	(7.12)**	(6.43)**	(0.10)
Options volume (OVOL)	−0.42E-03	−0.74E-03	−0.51E-02
	(−1.51)	(−2.87)**	(0.84)
Strategy (S = 0 for Long futures;	−0.02	−0.61	12.15
S = 1 for short futures)	(−0.03)	(−1.18)	(1.61)
Adj. R^2	0.0457	0.0199	−0.0016
F	47.63**	19.76**	0.92
Number of Observations	6195	5885	310
Chow test F-statistics = 4455.93**			

Panel (B): Non-members

Constant	3.27	9.82	39.68
	(0.84)	(2.54)**	(0.30)
Intraday std dev. of futures prices (σ)	6013.94	2342.41	−394.91
	(1.97)*	(0.70)	(−0.02)
Time to maturity (T)	0.46	0.52	−3.09
	(3.18)**	(4.46)**	(−0.76)
Moneyness (M)	3.25	−1.15	19.41
	(2.16)*	(−0.86)	(1.20)
Futures volume (FVOL)	0.50E-03	0.24E-03	−0.69E-03
	(2.76)**	(0.99)**	(−0.54)
Options volume (OVOL)	−0.16E-02	−0.86E-04	0.13E-02
	(−1.69)	(−0.95)	(0.08)
Strategy (S = 0 for long futures;	−2.04	−4.25	23.27
S = 1 for short futures)	(−0.89)	(−2.24)*	(1.20)
Adj R^2	0.0408	0.0171	−0.0115
F	10.60**	4.59**	0.66
Number of Observations	1540	1424	116
Chow test F-statistics = 452.88**			

t-statistics are in parentheses.
**1% significance level.
*5% significance level.

Appendix A

Panel (A): Descriptive Statistics for Volume and Volatility Before the Asian Financial Crisis (January 1996 to June 1997)

	Number of Days	*Mean*	*Std.*	*Max*	*Median*	*Min*
Futures Volume (No. of Contracts/day)	371	15812.73	5301.46	36451.00	15333.00	2469.00
Options Volume (No. of Contracts/day)	371	2638.63	1285.96	8549.00	2499.00	91.00
Intra-day Volatility (Basis Points)	371	3.27	1.93	25.57	2.88	1.73
Panel (B): Descriptive Statistics During the Asian Financial Crisis (August 1997, October 1997, January 1998 and February 1998)						
Futures Volume (No. of Contracts/day)	79	26653.84	11219.21	69719.00	26050.00	5917.00
Options Volume (No. of Contracts/day)	79	2533.24	1493.26	7352.00	2463.00	113.00
Intra-day Volatility (Basis Points)	79	8.58	9.47	58.98	5.91	2.27
Panel (C): Descriptive Statistics During the Asian Financial Crisis (Days with 2% changes in Hang Seng Index from July 1997 to July 1998)						
Futures Volume (No. of Contracts/day)	111	25136.14	10235.20	64868.00	23368.00	4775.00
Options Volume (No. of Contracts/day)	111	2734.98	1502.43	8513.00	2628.00	171.00
Intra-day Volatility (Basis Points)	111	6.72	5.40	47.37	5.29	2.04
Panel (D): Descriptive Statistics During Hong Kong Government Intervention (August 14 to 28 1998)						
Futures Volume (No. of Contracts/day)	10	50140.90	13537.78	66904.00	50385.00	29048.00
Options Volume (No. of Contracts/day)	10	5607.70	1001.34	7871.00	5508.00	3973.00
Intra-day Volatility (Basis Points)	10	8.10	2.17	12.59	7.70	4.59

CONCLUSIONS

We study the impact of the Asian financial crisis on the index options and index futures markets in Hong Kong. Time-stamped transaction data of the Hang Seng Index options and futures contracts from 1 January 1996 to 31 August 1998 were employed. The results show that during the Asian financial crisis and the government intervention period, the arbitrage profits and the standard deviations of these profits increased in both ex-post and ex-ante analyses. We argue that during the crisis and intervention periods, the market volatility brought a higher arbitrage profit level, however, despite this increased market volatility, the profitability of the arbitrage trades declined substantially with longer execution time lags in the ex-ante analysis. This suggests that the HSI futures and options markets are mature and efficient. A multiple regression analysis on the ex-post arbitrage profit also finds that there were structural changes in the pricing behavior of the derivative markets during the Asian financial crisis and the Hong Kong government intervention periods.

BIBLIOGRAPHY

Brennan, M. J., & Schwartz, E. S. (1990). Arbitrage in stock index futures. Journal of Business, (63)1, 7–31.

Cheng, L. T. W., Fung, J. K. W., & Pang, C. (1998). Early unwinding strategy in index options-futures arbitrage. Journal of Financial Research, winter, 447–461.

Cornell, B., & French, K. R. (1983). Taxes and the pricing of stock index futures. Journal of Finance, (38)3, 675–694.

Fleming, J., Ostdiek, B., & Whaley, R. E. (1996). Trading costs and the relative rates of price discovery in stock, futures, and option markets. The Journal of Futures Markets, (16)4, 353–387.

Fung, J. K. W., Cheng, L. T. W., & Chan, K. C. (1997). The intraday pricing efficiency of Hong Kong Hang Seng index options and futures markets. The Journal of Futures Markets, (17)7, 797–815.

Fung, J. K. W., & Fung, A. K. W. (1997). Mispricing of index futures contracts: A study of index futures versus index options contracts. Journal of Derivatives, winter, 37–44.

Kawaller, I. G. (1987). A note: Debunking the myth of the risk-free return. The Journal of Futures Markets, (7)3, 327–331.

Klemkosky, R. C., & Lee, J. H. (1991). The intraday ex post and ex ante profitability of index arbitrage. The Journal of Futures Markets, (11)3, 291–311.

Lee, J. H., & Nayar, N. (1993). A transactions data analysis of arbitrage between index options and index futures. The Journal of Futures Markets, (13)8, 889–902.

Modest, D. M., & Sundaresan, M. (1983). The relationship between spot and futures prices in stock index futures markets: Some preliminary evidence. The Journal of Futures Markets, (3)1, 15–41.

Stoll, H. R. (1969). The relationship between put and call option prices. Journal of Finance, (24)5, 801–824.

Tucker, A. L. (1991). Financial futures, options and swaps. St. Paul, MN.: West Publishing Company.