MISPRICING OF INDEX FUTURES CONTRACTS AND SHORT SALES CONSTRAINTS

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This article examines if changes in short sales constraints affect the extent to which index futures contracts are mispriced. In particular, the study analyzes the mispricing of the Hong Kong Hang Seng Index futures contracts. Tests are conducted over three distinct regulatory regimes relating to the short selling of stocks in Hong Kong. This permits a study of how changes in short selling regulations affect the mispricing of futures contracts. The study indicates that relaxing the constraints on short selling reduces the extent of futures mispricing. Multiple regression analysis is used to test the relationship between the magnitude of mispricing and various economic factors including cash market volatility, time-to-maturity of the contract, trading cost, and dividend payout rates. The study also finds that lifting of the short selling restrictions speeds up market adjustment, especially when a

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long-hedge (long futures, short stock) signal is detected. © 1999 John Wiley & Sons, Inc. Jrl Fut Mark 19: 695–715, 1999

INTRODUCTION

The popularity and growth in use of index futures contracts worldwide reflects the usefulness of the contracts to various classes of users, including institutional investors, speculators, and arbitrageurs who profit from any misalignment in the index level and the futures price. The extent of mispricing and the potential arbitrage profits has been a subject of considerable interest to academics, with a number of studies reporting significant differences between observed stock index futures prices and theoretical futures prices. In highly competitive financial markets we would expect the extent of mispricing to be small and the level of arbitrage profits to reflect the severity of real market frictions, including trading and market-impact costs, execution risks, and restrictions on the short selling of stocks.

Trading, market impact costs, and execution risks have all been the focus of a considerable volume of research. Less attention has been focused on the difficulties caused by the prohibitions on short selling in most markets. It is widely accepted that restrictions preventing the short selling of shares impede the arbitrage process. In the absence of being able to observe the imposition or lifting of short sale restrictions, studies of short selling in the United States and other markets have resorted either to an intermarket comparison or to an intramarket analysis over different market conditions. Recent regulation changes in the Hong Kong securities markets now allow for the first time direct observation of the effects on the arbitrage process of reductions in short sale constraints over time. Short sales constraints in Hong Kong were partially lifted in 1994 and then more comprehensively removed in 1996. The impact on mispricing of the lifting of short sale restrictions is the primary focus of this article.

We find that the removal of restrictions on short selling reduces the size and frequency of mispricing and speeds up the process of adjustment, with most of the change occurring with the first relaxation of short selling restrictions in 1994, a reflection of the size and importance of the stocks for which short selling was allowed. The relaxation of short sales constraints not only reduces the underpricing of the futures contract, but also narrows the no-arbitrage window reducing the magnitude of overpricing. Early unwinding of an initial long futures (short stock) arbitrage portfolio may exert downward pressure on the futures price and reduce

the extent of the overpricing of the futures contract. Both overpriced and underpriced futures display a reduction in the magnitude of mispricing after the first change in the short selling regulations.

INDEX MISPRICING AND SHORT SALES CONSTRAINTS

Considerable research has been conducted on the mispricing of various U.S. futures contracts[1] whilst the growth of futures markets elsewhere has stimulated research. Despite the importance of Hong Kong's futures markets, however,[2] few studies of mispricing are available. The best known study of arbitrage efficiency between the contract and the underlying Hang Seng index is that of Ho, Fang, and Woo (1992), although the study uses only a limited data set covering 17 trading days between April and July 1991. The study found overpricing to be more frequent than underpricing but concluded that it was difficult to realize arbitrage profits because of the trading system then in operation. A number of studies have examined the relative pricing efficiency between the futures contract and the index options traded in Hong Kong (Fung, Cheng, & Chan, 1997; and Fung & Fung, 1997a). The studies generally conclude that the futures are priced efficiently relative to the options. Cheng, Fung, and Pang (1999) show that an early unwinding strategy provides incremental profit in the arbitrage between the futures and the options contracts.

A number of authors have noted the possible importance of short sale constraints but little empirical evidence on their impact is available. Pope and Yadav (1994) provide a clear explanation of the impact of short sales constraints on index stocks and note that, if short sales are prohibited, short arbitrage is impossible except for market participants already owning equity stocks. To examine the effect of short sales restrictions they exploit a particular feature of the London Stock Exchange, the Account period, now abolished, which effectively allowed investors to short sell within an Account. During an Account period spanning a futures maturity date, there is no need for an arbitrageur to borrow stocks to exploit negative index future mispricing, and hence negative mispricing should be reduced. They conclude that short sales constraints and costs

[1]Sutcliffe (1997) provides an excellent overview of the literature.

[2]The Hong Kong stock market was ranked eighth in the world by market capitalization at the end of 1996. Futures on the Hang Seng index (HSI) have traded in Hong Kong since 1986 with ever-increasing volumes. The average daily trading volume of the HSI contract grew from 10,236 in 1993 to 18,685 contracts in 1996, with an average over the 4-year period of 16,188 contracts, equivalent to HK$8.094 billion (around US$1.038 billion assuming a multiplier of HK$50 per index point and an average index value of 10,000).

are a significant factor leading to futures underpricing relative to the cash index. Kempf (1998) also concluded in his study of the German market that constraints against short-sales do affect mispricing: "Overall, the tests suggested that short selling restrictions and early unwinding opportunities are influential factors for the behavior of the mispricing." Fung and Jiang (1999) adopt an error-correction model and examine the index-futures dynamic relationships in the Hong Kong markets. They find that the lifting of short-sales restrictions improves the integration between prices in the futures and the cash markets.

In contrast, Chung, Kang, and Rhee (1994) in their study of the Japanese markets note that the number of short arbitrage opportunities is small (3.4% in their sample) and that the results are about the same as those for comparable long arbitrage. On this basis they suggest that difficulties in short sales of stocks are not a major reason for big surges in the mispricing of futures contracts. This view agrees with that of Neal (1996), who argues that short-selling restrictions should not substantially affect the pattern of futures mispricing because institutions account for half of the arbitrage trades. For institutions that already own the stock, restriction against short selling cannot impede the process of quasi-arbitrage (selling instead of shorting stocks, and going long in futures) when the future is underpriced.

Both MacKinlay and Ramaswamy (1988) and Kempf (1998) provide arguments for expecting wider pricing effects to result from the removal of short sales constraints. MacKinlay and Ramaswamy note that the option to unwind early introduces path dependence in the mispricing behavior. The early unwinding option narrows down the no-arbitrage window because it is possible to capture extra profit from the reversal of mispricing errors. This is true both for initial short-futures and long-futures positions. MacKinlay and Ramaswamy found it less likely for the mispricing to be positive if the previous mispricing was negative because the unwinding trades stop the mispricing errors from crossing the arbitrage bounds. Relaxing short-sales constraints allows the arbitrageur to establish long-futures (short stock) arbitrage portfolios. This reduces the potential profitability of long-futures arbitrage (and the magnitude of futures underpricing). The possibility of early unwinding also makes it possible to open an initial long-futures portfolio earlier. When the mispricing approaches the boundary (specifically, the upper bound of the futures price), the arbitrageurs begin covering (or unwinding) their initial long-futures portfolio. This checks the upward movement of the futures price and prevents it from drifting above its upper bound.

Kempf (1998) introduces a model that predicts that pricing is path dependent. The model takes into account the holding cost of a short position and indicates that negative mispricing need not be driven back to zero by arbitrageurs, but instead may remain negative, the level depending on the holding costs arising from short selling. The argument underscores the impact of short selling and the need to consider the cost of establishing a short position. The existence of differential costs, he suggests, should mean that positive mispricing behaves differently to negative mispricing.

Model and Hypotheses

The cost of carry relationship (Klemkosky and Lee, 1991) is computed as

$$F_i^* = S_i(1 + r - d)^t \quad (1)$$

where F_i^* denotes the "fair" futures price implied by the synchronous index price (S_i) via the cost-of-carry relationship, r represents the riskless rate of interest, d the dividend payout rate of the index portfolio, and t is the time-to-maturity (as a fraction of a year) of the futures contract.

If the futures price is above its fair value ($F > F^*$), then an arbitrageur may buy the index (portfolio) and hedge the exposure by taking a short position in the futures (short-hedge arbitrage). The arbitrageur finances the equity position with a risk-less loan and with the future dividends. If the futures price is below its fair value ($F < F^*$), then the arbitrageur may sell short the index and hedge the position by going long in the futures (long-hedge arbitrage). Those who already own the stocks may simply sell their stocks and substitute for their equity exposure with a "cheap" futures contract. The proceeds from selling the stock are invested in a risk-less asset. The futures position locks in the price at which the stock may be bought back. Arbitrageurs who do not own the stocks short sell and then invest the proceeds in a risk-less asset. This is used for buying back the index in the future and for compensating the stock lender for future dividends.[3]

Taking transaction costs into consideration, the upper bound (F^U) and lower bound (F^L) for the futures prices can be written as:

$$F^U = F^* + m_f + m_s$$

$$F^L = F^* - m_f - m_s \quad (2)$$

where m_f and m_s represent, respectively, the round-trip trading and mar-

[3]See Modest and Sundaresan (1983) and Cornell and French (1983) for detailed proofs.

ket-impact costs for the futures contract and the index portfolio.[4] The trading and market-impact costs can be decomposed as follows:

$$m_f = 2\tau_f + \phi_f; \text{ and}$$

$$m_s = (\tau_s + \phi_s)(S_i + S_T^a) + \lambda_s \tag{3}$$

where τ_f and ϕ_f denote the one-way exchange trading fee and market-impact cost (all in index points) for futures trading, and τ_S and ϕ_S are the one-way exchange trading fee and market-impact costs (all in fractions of the index value) for equities trading, λ_S denotes the round-trip miscellaneous trading fee (including transfer deed duty and transfer fee) for the index portfolio and S_T^a is the settlement value of the index. This is equal to an arithmetic average of the index taken every 5 minutes during the last trading day.

Following MacKinlay and Ramaswamy (1988) and Yadav and Pope (1994), this analysis examines the distribution of the mispricings relative to the cash spot index. Relative mispricing is defined as:

$$\begin{aligned} e/S &= (F - F^U)/S && \text{if } F > F^U \\ &= (F - F^L)/S && \text{if } F < F^L \text{ (and in this case } e \text{ is negative)} \\ &= 0 && \text{otherwise} \end{aligned}$$

where F is the actual price of the future.[5]

Viewing short sales constraints as a source of asymmetric transaction costs (Pope & Yadav, 1994), the transaction costs facing arbitrageurs will be higher if short selling is regulated. Short sales restrictions and market practice impede short stock arbitrage in a number of ways. Because short-sellers have to borrow stocks before they can sell short, they have both

[4]The option to early-unwind reduces the width of the no-arbitrage window (Brennan & Schwartz, 1990). Its impact on the distribution of mispricing should be magnified after the lifting of restrictions against short-sales.

[5]The relative magnitude of over-pricing and under-pricing are defined in a similar fashion as

$$\begin{aligned} e^+/S &= (F - F^U)/S && \text{if } F > F^U \\ e^-/S &= (F^L - F)/S && \text{if } F < F^L \\ &= 0 && \text{otherwise} \end{aligned}$$

The relative absolute value of mispricing is defined as:

$$\begin{aligned} |e|/S &= e^+/S && \text{if } F > F^U \\ &= e^-/S && \text{if } F < F^L \\ &= 0 && \text{otherwise} \end{aligned}$$

to locate a willing stock lender and to pay a stock borrowing fee. In addition, they are unable to use the proceeds from short selling. The cost ranges from zero for those already owning the stock (and who use a stock substitution strategy by selling stock and going long in futures) to a potentially high level. Tick rules against short sellers also increase frictions and possibly delay arbitrage whilst prohibitions against short selling provide an extreme barrier to short-stock arbitrage because only those who already own the stock may take advantage of futures underpricing. Hence reduction in the constraints on short selling should reduce transaction costs, increase the efficiency of the market, and reduce mispricing opportunities in the market. Consequently the overall profitability and frequency of mispricing opportunities will diminish with the lifting of restrictions on short selling. Mispricing opportunities should also decline for long and short hedges.

The improved ability to create long hedge positions as a result of the lifting of short sale restrictions should increase the speed of reaction of the market. Traders will be able to react more swiftly to mispricing opportunities and to extinguish them more rapidly so that the speed of adjustment will be faster after the removal of short sale restrictions. In particular, adjustment after underpricing should be faster, and profits (losses) will decrease (increase) over longer adjustment intervals.

We express these ideas of the effects of short sales constraints more formally as three hypotheses.

Hypothesis 1: The lifting of short sale restrictions reduces the difficulty associated with long-hedge arbitrage (that is, short stock, long futures). This reduces the magnitude and frequency of futures underpricing. Hence the relative absolute value of mispricing, $|e|/S$ should be smaller after the change.

Hypothesis 2: Because it is easier to initiate a long-hedge arbitrage portfolio, arbitrageurs may adopt an early-unwinding strategy to capture a reversal in the mispricing when the futures become overpriced. This will reduce the magnitude of overpricing, because arbitrageurs may immediately close their long futures and cover their short stock positions when the futures price rises above its fair value (or the costs associated with holding a short position). Hence lifting the short sales restriction will also reduce the extent of overpricing of the futures.

Following from hypotheses one and two, the impact of the lifting of the short sales restrictions will be symmetric for the distribution of mispricings. The deviation around the fair value should be reduced on both sides.

Hypotheses 3: Lifting of the short sales restrictions should ease the arbitrage processes both for underpricing and overpricing. Consequently, the adjustment to equilibrium prices will be more rapid so that ex-ante arbitrage profitability will decline faster with the lapse of time after the change. The effect may be more pronounced with underpricing. These effects follow from hypotheses 1 and 2 because the tightening of the arbitrage window will increase the relative attractiveness of any given level of mispricing compared with the previous no-arbitrage window. At the same time, the growth in stock borrowing and the removal of tick rules following the relaxation of the short-selling restrictions will reduce the inconvenience of arbitrage so helping to speed up the arbitrage process.

DATA

The most actively traded futures contracts are those for the current month. To reduce thin trading problems these contracts are the focus of this study. Other months are excluded as is expiration-day data to eliminate any potential bias arising from the settlement method of the HSI contracts.

Time-stamped transactions data of the Hang Seng Index Futures contracts for the period 1 April 1993 to 30 September 1996 were obtained from the Hong Kong Futures Exchange. Minute-by-minute index prices and annualized month-end dividend yields for the same period were provided by Hang Seng Index Services Ltd.[6] Middle quotes of the Hong Kong Inter-bank Offer Rates (HIBOR) were retrieved from Datastream. To alleviate the asynchroneity problem between the index and the futures prices, each minute-by-minute index price is matched with the nearest futures price so that there is at most one matched futures-index pair for each one-minute interval.

The HK contract is written on the Hang Seng Index, a market value-weighted index composed of 33 stocks that account for more than 70% of the total market capitalization of all the stocks listed on the Stock Exchange of Hong Kong (SEHK). The contract is cash settled, with settlement on the last business day of the month. The expiry (or last trading) day is the business day prior to the settlement day. The settlement value of the contract is set equal to an average value of the index taken at five-minute intervals during the expiry day. Fung and Fung (1997b) show that

[6]The index is calculated using the last traded price for each stock. Following Sofianos (1993), because some stocks are traded at their bid and the others are traded at their ask, the index should be close to the midquote.

the conventional cost-of-carry relationship[7] holds for HSI contracts before the last trading day.

By using a sample period covering April 1993 to September 1996, the study is able to capture the possible impact on index mispricing of changes in regulatory regimes that affect short selling. Within the study period, two major changes in short-sales restrictions occurred. Short selling was prohibited before 3 January 1994. From that date, the Stock Exchange of Hong Kong (SEHK) allowed 17 out of the 33 constituent stocks of the Hang Seng Index (HSI) to be sold short, subject to restrictions. These stocks represented the largest, most liquid and actively traded stocks on the HK market. As such, we would expect the number of mispricing opportunities to fall dramatically once the short sales restrictions were lifted. The restrictions that remained after the first relaxation included the "up-tick" rule, which stipulated that stocks could only be short sold at prices above that of their previous trade, and the levying of stamp duty on the borrowed shares if the short position was not covered in two weeks. These restrictions were lifted[8] on 25 March 1996, at the same time as 113 of the shares listed on the exchange including all the constituent stocks of the index were allowed to be sold short.[9]

Thus our study identifies three distinct regimes. During regime 1, prior to January 1994, short selling was prohibited in Hong Kong. In regime 2, from January 1994 until March 1996, short selling was possible on just over half the stocks in the Hang Seng index. This allowed short selling of a proxy for the index, but with the possibility of substantial tracking error so that arbitrage possibilities were imperfect. From April 1996, regime 3 permitted all of the index stocks to be sold short, allowing much more complete and effective arbitrage to take place.

The existence of mispricing is not of itself necessarily important. What is crucial is its size relative to transactions costs and its persistence over time. Transaction costs consist of the exchange trading fees charged to member firms by the Hong Kong Futures Exchange (HKFE) and the Stock Exchange of Hong Kong (SEHK). For futures, a fee of 0.24 index points is used, and for equities, 0.17% of value.[10] The round-trip miscellaneous trading fee for the index portfolio is estimated to be three index

[7]Cornell and French (1983); Modest and Sundaresan (1983).

[8]The Stock Exchange hoped that stock borrowing and lending and short selling would become popular after changes to stamp duty took effect in 1991. However, restrictions on relief meant that the market did not develop and further regulation changes were necessary.

[9]Only members of the exchange are able to sell short the designated securities. They may sell them on their own account or on behalf of clients. Short selling without borrowing sufficient securities to cover the sale ("naked short selling") is an offence under the Securities Ordinance of HK.

[10]The fees were slightly lower in the post-January 1995 period, 0.23 for futures and 0.163 for equities.

points. The minimum bid–ask price spread for stocks is fixed according to a "spread table" set by the SEHK. In this study, the one-way market-impact cost is proxied by calculating one half of the average of the percentage spreads that span the prices of every index stock[11] (Mak & Lam, 1996). The SEHK lowered the official spreads on 1 July 1994 and revised them upward on 1 January 1995, although the average spread after the last revision remained lower than before 1 July 1994. The minimum spread should be a good approximation of the actual bid–ask spread, because the constituent stocks of the index are typically the most actively traded (SEHK Fact Book, various issues). For the August 1993 to June 1994 period we use an equity bid ask spread of 0.3314%, and for the post-January 1995 period a spread of 0.2391%. Traders and officials estimate the bid–ask spread for the spot month futures contracts to be five index points.[12]

The efficiency of trading is also indicated by the speed of response to mispricing. We would expect mispricing and hence profit opportunities to disappear the longer the time that elapses after the initial observation of the mispricing. For long hedge arbitrage signals (e^-), which suggest shorting the stock and going long in the futures, further improvement in the speed of response might be expected after short selling restrictions are removed. However, for short hedge arbitrage signals, which involve a strategy of going long in the stock and short in the futures, we would expect no further improvement once short selling restrictions are lifted, because the removal of restrictions does not affect the ease with which the strategy may be followed. To test these expectations the change in the profitability (Δe) of the arbitrage strategy after a time lag L is regressed on the length of the lag and a dummy variable representing the periods before and after the change in the short selling regulations in 1994.

$$\Delta e = \beta L + \Delta\beta L D_t + \varepsilon$$

Δe is the change in profitability in the arbitrage strategy after a particular time lag L where L ranges through 3, 5, 10 and 15 minutes. $\Delta e = P_L^+ - e^+ > 0$ if $e > 0$ and $\Delta e = P_L^- - e^-$ if $e < 0$. The magnitude of the signal

[11]The market impact cost used here is limited to the bid–ask spread and does not include any effect on prices as a result of arbitrage operations.

[12]In the majority of studies, market impact costs (bid–ask spread) have been calculated only for the opening equity position. No such cost is assumed for the closing of the position. This is appropriate for markets where market-on-close or market-on-open orders are available, and the settlement value of the contract depends only on the closing or opening value of the cash index. However, in unwinding the equity position of the HSIF contract, the equity leg has to be closed out evenly throughout the last trading day by buying or selling a fraction of the position at the end of every five-minute interval. This creates an additional market-impact cost at closing.

(initial profitability) is determined by e. P_L is the (ex-ante) profitability of the strategy. β is the slope coefficient in period 1, $\Delta\beta$ the change in the slope coefficient in period 2 relative to period 1. D_t is a dummy variable with the value 0 in the period before short selling restrictions are relaxed, and 1 after relaxation. The regressions are carried out using all arbitrage signals, short hedge arbitrage signals only, and long hedge arbitrage signals only.

β is expected to be negative. The longer the time elapsed after mispricing is observed, the larger the drop in profitability. $\Delta\beta$ should also be negative once short selling restrictions are removed, especially for long-hedge arbitrage signals. Short-hedge arbitrage should be less affected by the lifting of restrictions so that $\Delta\beta$ should not be significant in that situation.

IMPACT OF SHORT SELLING ON MISPRICING

Short sales restrictions impede long-hedge arbitrage (long futures and short stock), due to the cost and inconvenience involved in selling short the entire index portfolio. The lifting of short sales restrictions should reduce the frictions involved in accomplishing long-hedge arbitrage and should reduce the extent and frequency of futures underpicing. Lifting of the short sale restrictions may also make short-hedge arbitrage portfolios more difficult to establish, because early unwinding of an initial long-hedge arbitrage portfolio will prevent the futures price from drifting too far above its fair value, and will reduce the extent and frequency of short-hedge (short futures and long stock) arbitrage profit opportunities. Consequently we should observe a shrinking in both the magnitude of underpricing and overpricing, and in the frequency of occurrence too.

Ex-post Arbitrage Profits

Table I summarizes the extent of overpricing and underpricing, and provides the distribution of the pricing errors between the spot month futures contract and the index. We report results for both the case of zero transaction costs (panel A) and for transaction costs compatible with being a member of the exchange (panel B). The evidence on early unwinding (Sofianos, 1993) suggests that traders establish positions that don't cover all the transaction costs. The trader's position is liquidated early, when overpricing switches to underpricing and additional price benefits are captured. The appropriate level of costs will therefore lie somewhere between zero and those payable by members. The zero transaction cost

TABLE I

The Distributions of Ex-post Pricing Errors for the Entire Sample Period and Around the Event Dates

	Overall (01/04/1993–30/09/1996)						*Period 1 Before 1994 changes (01/09/1993–30/11/1993)*						*Period 2 After 1994 changes (01/02/1994–30/04/1994)*					
	Mean	*Med*	*95%*	*99%*	*Std*	*N*	*Mean*	*Med*	*95%*	*99%*	*Std*	*N*	*Mean*	*Med*	*95%*	*99%*	*Std*	*N*
Panel A: Zero Cost																		
e/S	5.2	4.3	76.9	120.2	43.6	172678	4.9[a]	−6.6	132.5	183.1	74.6	11234	21.5[a]	26.8	108.0	137.8	52.6	11093
lel/S	33.8	27.4	87.7	129.3	28.1	172678	62.5	59.0	134.5	183.3	41.0	11234	46.5	41.7	112.6	139.2	32.7	11093
e^+/S	35.8	28.7	92.7	136.3	29.8	93982	71.1	65.5	157.6	201.2	47.1	5332	48.2	42.7	117.3	141.3	33.1	7823
e^-/S	31.3	25.8	81.6	117.2	25.7	78696	54.8	53.8	108.9	125.4	32.6	5902	42.5	38.8	97.8	126.2	31.4	3270
Panel B: Member																		
e/S	13.8	8.95	69.2	106.9	33.46	4190	27.6[a]	20.1	89.1	127.3	37.0	1271	17.7[a]	18.0	47.3	65.8	24.7	758
lel/S	23.6	15.3	72.9	112.8	27.3	4190	31.7	21.6	89.3	127.3	33.5	1271	23.0	20.0	50.0	90.2	20.8	758
e^+/S	26.6	18.8	78.6	112.8	27.7	2937	36.5	28.0	95.0	139.1	35.1	1032	23.0	21.0	48.5	72.9	17.2	669
e^-/S	16.6	9.7	52.9	113.7	25.2	1253	11.0	7.5	31.1	62.4	12.1	239	22.7	11.1	78.0	240.6	33.7	89

Note: all ratios are expressed in basis points and all figures are rounded to 1 decimal place. [.] shows percentage of total.

	Period 3 Before 1996 changes (01/12/1995–02/1996)						*Period 4 After 1996 changes (01/05/1996–30/07/1996)*					
	Mean	*Med*	*95%*	*99%*	*Std*	*N*	*Mean*	*Med*	*95%*	*99%*	*Std*	*N*
Panel A: Zero Cost (cont.)												
e/S	35.7[a]	36.1	80.7	98.2	29.7	12640	6.4[a]	7.6	47.4	63.4	26.0	13153
lel/S	39.2	36.8	81.3	98.2	25.0	12640	21.6	18.8	50.2	66.0	15.7	13153
e^+/S	42.1	40.8	82.3	101.1	24.2	11248	22.7	20.0	51.7	67.4	15.9	8118
e^-/S	15.5	10.7	44.3	87.7	16.8	1392	19.9	16.7	47.8	59.5	15.3	5035
Panel B: Member (cont.)												
e/S	11.6[a]	8.3	31.8	40.8	10.4	313	3.7[a]	−2.3	47.8	47.8	36.5	6
lel/S	11.3	7.9	31.7	38.7	10.3	313	25.7	24.7	52.2	52.5	23.6	6
e^+/S	11.6	8.3	31.8	40.8	10.3	299	44.1	44.1	47.8	47.8	5.2	2
e^-/S	3.9	2.0	11.7	11.7	3.9	14	16.5	6.1	52.2	52.2	24.1	4

$e/S = (F - F^U)/S$ if $F > F^U$
$= (F - F^L)/S$ if $F < F^L$ (and in this case e is negative)
$= 0$ otherwise

$e^+/S = (F - F^U)/S$ if $F > F^U$
$e^-/S = (F^L - F)/S$ if $F < F^L$
$= 0$ otherwise

$lel/S = e^+/S$ if $F > F^U$
$= e^-/S$ if $F < F^L$
$= 0$ otherwise

[a]Significantly different from zero at 1% level.

Period 1 corresponds to the period before any relaxation of short sales constraints. Period 2 is the period after the first relaxation of constraints. Period 3 is the period immediately before the second relaxation of constraints in 1996, and period 4 the period immediately after.

panel will overstate the effects of mispricing and the opportunities for arbitrage. In contrast, as a result of early unwinding the transactions cost panel will understate the opportunities for arbitrage.

In the absence of transaction costs the mean percentage pricing error (e/S) over the whole period is 5.2 basis points over a sample of 172,678 observations. Futures are generally overpriced in Hong Kong (in contrast to the results of similar studies for other exchanges[13]), and the average magnitude of the overpricing is greater than the underpricing.

$|e|/S$ provides an estimate of the overall magnitude of the pricing error in percentage terms. If our hypothesis (that short sales restrictions impede the process of arbitrage) is correct, we would expect the value of $|e|/S$ to fall as short sales constraints are relaxed. The overall value for the whole period of $|e|/S$ is 33.8 basis points (bps). The other entries in panel A examine both overpricing (e^+/S representing the positive pricing errors) and underpricing (e^-/S representing the negative pricing errors). Panel B indicates the position that assumes traders must pay a level of transaction costs appropriate to members of the Exchange. The number of mispricing opportunities is reduced to 4,190 overall, and the mean percentage pricing error (e/S) over the whole period for these opportunities is 13.8 basis points.

Table I also reports the result of constructing three-month windows on either side of the regulation changes with regard to short selling in 1994 and 1996.[14] Panel A provides evidence of mispricing immediately before and after the changes in 1994, and immediately before and after the changes in 1996. The columns labeled Period 1 (01/09/1993–30/11/1993) correspond to a situation in which no short selling is allowed. The columns labeled Period 4 (01/05/1996–30/07/1996) correspond to a period when short selling was allowed in all the index stocks. $|e|/S$ falls[15]

[13]See for example, Cornell and French (1983), who found S&P contracts to be under-priced; Modest and Sundaresan (1983), who study both the S&P 500 and NYSE composite contracts and attribute the discount to the inability of the trader to fully use the proceeds from short selling stocks; and Chung (1991), who examined the Major Market Index and found the deviations smaller than for previous studies. However, the MMI consists of only 20 stocks. Outside of the U.S., Brenner, Subrahmanyam, and Uno (1989) found the Nikkei contracts to be generally underpriced, whereas Yadav and Pope (1994) observed that the FTSE 100 contracts were more frequently underpriced and that the average magnitude of underpricing exceeds that of overpricing.

[14]The table was constructed using an event study methodology (Brown & Warner, 1985). Data for the month before and after the event date (deregulation day) was excluded. The three-month period before the exclusion interval is then compared with the three-month period after the exclusion interval.

[15]e/S indicates whether on average the market overprices or underprices the futures contract. It is not suitable as a measure of the change in mispricing because e can be both positive and negative, so that large positive and large negative mispricings can cancel each other out and indicate that on average there is no mispricing. $|e|/S$ ignores the sign of the mispricing and does not suffer from this canceling-out effect. However, the variance of e/S is a good measure of changes in market efficiency. A lower variance of e/S implies that the actual futures price is closer to the no-arbitrage value.

from 62.5 bps before any short selling is allowed to 46.5 bps in the period following the relaxation of controls on 17 stocks in March 1994. There is clear evidence of a reduction in mispricing as a result of the relaxation of short selling constraints. For the second set of short sale changes in 1996 mispricing in the three months prior to the change is, on average, 39.2 bps. After the relaxation of short selling restrictions on all index stocks, the mispricing falls to 21.6 bps. The changes between periods are statistically significant (Table II), as tests (1) and (2) for the mean values and (5) and (6) for the median values indicate. These results are repeated for both overpricing and underpricing for the first relaxation, and for overpricing (but not underpricing as a result of too few observations) for the total lifting of restrictions on index stocks in 1996.

In the presence of transaction costs (Table I, Panel B), the first relaxation in 1994 results in a fall from 31.7 bps to 23.0 bps and reduced mispricing. The 1994 relaxation of constraints related to the largest, most actively traded stocks. These stocks comprised the majority of the stocks in the Index by number and a much larger proportion by value. Arbitrage activity is overwhelmingly concentrated in these stocks. We would expect the subsequent removal of short selling restrictions to have a further impact on mispricing. This is indeed what we find. After the second relaxation of short selling restrictions mispricing opportunities disappear.[16]

Ex-ante Arbitrage Profits

Table I indicates the extent of mispricing observed ex-post for different levels of transaction costs. This mispricing may persist only momentarily or for an extended period of time. To analyze ex-ante mispricing a short or long hedge is formed at the prices prevailing 3, 5, 10, and 15 minutes after the hedge initially signals mispricing (Klemkosky & Lee, 1991). Table III provides ex-ante tests of the profit opportunities, assuming that the mispricing is perceived and acted upon within intervals of 3, 5, 10, and 15 minutes for an arbitrageur who is a member of the exchange. The results are given in percentage form P/S (line 1). P is the profit or loss on the trade initiated after an arbitrage signal. P may be positive or negative. If P is persistently positive after an extended time delay, the market is slow to adjust. If P is negative after a short delay, the market is dynami-

[16]In period 3, 313 mispricing opportunities occur after allowing for transactions costs out of a total of 12,000 trades. In period 4 only 6 mispricing opportunities after transactions costs occur. The market has become highly arbitrage efficient. Note also that in a number of cases the mean value of the statistic goes up from period 1 to period 2, or period 3 to period 4. This is accompanied by a reduction in the number of observations and reflects the substantial reduction in the number of mispricings, so that only outliers remain. Similar instances are apparent in the ex post tables.

TABLE II

Results of Statistical Tests for Differences in Distribution of Percentage absolute error ($|e/S$) between the sub-periods

Panel A: Zero Cost

		Two-Sample Test for sub-period I and sub-period II		*Two-sample Test for sub-period III and sub-period IV*
$\|e/S$	(1)	H_0: $\mu_1 = \mu_2$ H_1: $\mu_1 > \mu_2$ (32.26)[b]	(2)	H_0: $\mu_3 = \mu_4$ H_1: $\mu_3 > \mu_4$ (52.70)[b]
	(3)	H_0: $\sigma_1 = \sigma_2$ H_1: $\sigma_1 > \sigma_2$ (1.57)[b]	(4)	H_0: $\sigma_3 = \sigma_4$ H_1: $\sigma_3 > \sigma_4$ (2.54)[b]
	(5)	H_0: $m_1 = m_2$ H_0: $m_1 > m_2$ (7.50)[b]	(6)	H_0: $m_3 = m_4$ H_1: $m_3 > m_4$ (12.54)[b]

Panel B: Member

		Two-Sample Test for Period I and Period II		*Two-sample Test for Period III and Period IV*
$\|e/S$	(1)	H_0: $\mu_1 = \mu_2$ H_1: $\mu_1 > \mu_2$ (7.22)[b]	—	N.A.[c]
	(3)	H_0: $\sigma_1 = \sigma_2$ H_1: $\sigma_1 > \sigma_2$ (2.59)[b]	—	N.A.[c]
	(5)	H_0: $m_1 = m_2$ H_0: $m_1 > m_2$ (0.70)	—	N.A.[c]

Notes:
m_i = Median of |e|/S in sub-period, I = 1, 2, 3, and 4
σ_i = Standard deviation of |e|/S in sub-period, I = 1, 2, 3, and 4
μ_i = Mean of |e|/S in sub-period, I = 1, 2, 3, and 4
[a]Significantly different from zero at 5% level.
[b]Significantly different from zero at 1% level.
[c]There are only six observations in sub-period four. So, we drop all tests between period 3 and 4
(1) shows that $\mu_1 > \mu_2$ at 1% level (2) shows that $\mu_3 > \mu_4$ at 1% level
(3) shows that $\sigma_1 > \sigma_2$ at 1% level (4) shows that $\sigma_3 > \sigma_4$ at 1% level
(5) shows that $m_1 > m_2$ at 1% level (6) shows that $m_3 > m_4$ at 5% level
1. A two sample t-test is used to test whether the mean of |e|/S are equal between periods.
2. A F-test is used to test whether the ratio of the variances of |e|/S deviates from unity.
3. A "median test" to test the test for equal proportions of two populations lie below the median. For sufficient sample size, the test statistics converges to a chi-square. (see page 530–533, Hawkins and Weber (1980).

cally efficient and the market is quick to adjust to the arbitrage signal. P^+ is the profit or loss after a short-hedge arbitrage signal (that is, e^+) and P^- is the profit or loss after a long-hedge arbitrage signal (that is, e^-). Profitability following a long-hedge arbitrage signal is expected to persist longer than that following a short-hedge arbitrage signal because of the extra costs and restrictions against short selling, particularly before

TABLE III

The Distribution of the Ex-ante Profit (Loss) for Members around Event Date

		Before 1994 changes (01/09/1993–30/11/1993)				*After 1994 changes (01/02/1994–30/04/1994)*				*Before 1996 changes (01/12/1995–02/1996)*				*After 1996 changes (01/05/1996–30/07/1996)*			
		Mean	*Med*	*Std*	*N*	*Mean*	*Med*	*Std*	*N*	*Mean*	*Median*	*Std*	*N*	*Mean*	*Median*	*Std*	*N*
Panel A: All arbitrage signals																	
3 Min	P/S	6.94[a]	17.13	71.45	1191	1.77	15.53	54.43	718	4.41[a]	3.77	17.59	260	−12.64[a]	14.79	49.42	13
5 Min	P/S	2.82	14.02	73.64	1171	−3.7	13.34	60.62	705	3.06[a]	3.46	17.99	251	−13.18[a]	13.95	13.17	13
10 Min	P/S	−3.5	11.19	77.28	1099	−7.4[a]	12.15	63.58	670	1.44	0.99	18.45	243	−124.5[a]	−133.5	28.99	13
15 Min	P/S	−9.2[a]	3.38	78.83	1058	−12.2[a]	10.88	67.39	631	0.1	1.49	19.51	234	−12.25[a]	−12.29	24.45	13
Panel B: Short-hedge arbitrage signal (e+)		*Before 1994 changes (01/09/1993–30/11/1993)*				*After 1994 changes (01/02/1994–30/04/1994)*				*Before 1996 changes (01/12/1995–02/1996)*				*After 1996 changes (01/05/1996–30/07/1996)*			
3 Min	P+/S	9.22[a]	21.51	74.95	1069	2.7	16.9	55.49	681	4.41[a]	3.77	17.59	260	−13.68[a]	−14.89	33.62	12
5 Min	P+/S	4.37	1.87	76.99	1064	−3.3	14.39	61.53	682	3.06[a]	3.46	17.99	251	−13.18[a]	−13.95	33.17	13
10 Min	P+/S	−2.9[a]	13.9	79.87	1087	−7.4[a]	12.63	64.05	660	1.44	0.99	18.45	243	−124.5[a]	−133.5	28.99	13
15 Min	P+/S	−9.2	7.23	81.19	997	−12.2[a]	11.33	67.66	626	0.1	1.49	19.51	234	−12.25[a]	−12.29	24.45	13
Panel C: Long-hedge arbitrage signal (e−)		*Before 1994 changes (01/09/1993–30/11/1993)*				*After 1994 changes (01/02/1994–30/04/1994)*				*Before 1996 changes (01/12/1995–02/1996)*				*After 1996 changes (01/05/1996–30/07/1996)*			
3 Min	P−/S	13.1[a]	9.2	12.98	122	15.3[a]	7.0	23.26	37	N.A	N.A	N.A.	N.A	1.6	1.6	N.A	1
5 Min	P−/S	12.6[a]	9.3	12.03	107	15.5[a]	11.4	16.69	23	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
10 Min	P−/S	11.5[a]	8.8	9.89	72	6.0[a]	3.8	5.15	10	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
15 Min	P−/S	10.1[a]	9.0	7.03	61	3.8	3.1	2.78	5	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A

Note: all ratios are expressed in basis points and all figures are rounded to 1 decimal place.

[a]Significantly different from zero at 1% level.

P is the profit or loss on the trade initiated after an arbitrage signal. *P* may be positive or negative. If P is persistently positive after an extended time delay, the market is slow to adjust. If *P* is negative after a short delay, the market is dynamically efficient and the market is quick to adjust to the arbitrage signal. P^+ is the profit or loss after a short-hedge arbitrage signal (ie e^+) and P^- is the profit or loss after a long-hedge arbitrage signal (ie e^-). *N* is the number of observations and the mean, median and standard (deviation) of profitability have the usual interpretation. The table shows the mean profitability after 3, 5, 10 and 15 minute lags from observation of the initial mispricing.

the lifting of the short sale restrictions. Significant profitable opportunities exist in period 1 for three minutes, but as short selling restrictions are removed these do not persist after the relaxation of short selling restrictions in period 2. Similarly, profit opportunities exist before the 1996 changes for up to five minutes but become smaller in the final period when short selling restrictions have been removed for all the index stocks. As the time lags increase, no period reveals profitable opportunities. Panels B and C provide a more detailed breakdown for P^+ and P^-. The picture for overpricing is as before with significant profit opportunities existing in both periods for three minutes immediately before the change in regulation, but with these opportunities extinguished after the change. When an underpricing signal is received, profits are possible but the magnitude and frequency of the profits falls over time, consistent with our hypothesis that the removal of short sales restrictions reduces the extent of mispricing.

Table IV reports the results of regressions using mispricing as the dependent variable for both zero and member level transaction costs.[17] For both levels of transaction costs the regression is run for the short sales changes in 1994, and for the more complete relaxation in 1996. For the 1994 changes the volatility of the index (σ), time to maturity (t), transaction costs (TC) and relaxation of short selling are all significant in determining mispricing for both levels of transaction costs. D represents a dummy variable associated with overpricing and underpricing ($D = 1$ for underpricing, 0 otherwise) and is negative as expected because the contracts are mainly over-priced. SS represent a dummy variable as-

[17]The following regression model is adopted:

$$|e|/S = \alpha_0 + \alpha_1\sigma + \alpha_2 t + \alpha_3 d + \alpha_4 D + \alpha_5 TC + \alpha_6 SS + \eta$$

σ is the intraday standard deviation of the minute-by-minute quotes of the index on the day the mispricing occurs, t is the time-to-maturity of the contract, d is the dividend yield, D is a dummy variable associated with over and under pricing ($D = 1$ for underpricing, 0 otherwise), TC is the total trading cost for members, SS represents a dummy variable associated with the change in short selling regulations. For the first change in short selling restrictions, $SS = 1$ with no short-selling, 0 otherwise. For the second change, $SS = 1$ for the period with restrictions, 0 otherwise. (α_j ($j = 0$ to 6) are the regression coefficients; η is the error term of the regression model. α_1 is expected to be positive because execution risk is higher in a volatile market. α_2 may be positive or negative. The longer the time to maturity of the contract, the greater the value of the early-unwinding option (Brennan & Schwartz, 1990), and arbitrageurs may require smaller mispricing in order to find it worthwhile to set up the (initial) positions; however, the mispricing converges to zero at maturity. α_3 depends on whether the ex-post dividend yield is accurately forecast by traders (Chance, Kumar, & Rich, 1996). (α_4 should be negative if the magnitude of overpricing is greater than that of underpricing on average, and vice versa. α_5 should be negative, because lower trading costs should reduce the width of the no-arbitrage window and reduce the range of the pricing errors. If the results are consistent with our hypothesis that reduced restrictions against short selling reduce mispricing, α_6 should be positive for both regressions, because lifting of the restrictions should reduce the magnitude of the pricing errors.

TABLE IV

Regression Results on the Analysis for the Effect of Various Economic Factors on the Relative Magnitude of Mispricing

	Period	*Dependent Variable*	*N*	α_0	α_1	α_2	α_3	α_4	α_5	α_6	R^2	*F*
Zero Cost	*Around 94 Changes*	|e|/*S*	22327	−0.001505 (−1.131)	0.0000393 (3.805)[b]	0.025128 (23.007)[b]	−0.013116 (−0.672)	−0.000742 (−13.370)[b]	0.00005185 (6.271)[b]	0.002464 (31.334)[b]	0.0996	411.5[b]
Member	*Around 94 Changes*	|e|/*S*	2029	−0.066814 (−10.895)	0.000009543 (3.477)[b]	0.031290 (9.775)[b]	1.000922 (10.461)[b]	−0.000137 (−0.406)	0.000393 (10.601)[b]	0.003163 (7.981)[b]	0.1536	61.1[b]
Zero Cost	*Around 96 Changes*	|e|/*S*	25289	−0.007754 (−4.725)[b]	0.000008892 (7.860)[b]	0.024124 (42.602)	−0.034126 (−1.446)	−0.000185 (−6.080)[b]	0.000104 (10.888)[b]	0.001729 (27.566)[b]	0.2450	1367.2[b]

Note: t-statistics in parentheses
[a]Significant at 5%
[b]Significant at 1%

Model 1: $|e|/S = \alpha_0 + \alpha_1\sigma + \alpha_2 t + \alpha_3 d + \alpha_4 D + \alpha_5 TC + \alpha_6 SS + \eta$

$|e|/S$ is the relative magnitude of mispricing for the two levels of transaction costs. σ is the intraday standard deviation of the minute-by-minute quotes of the index on the day the mispricing occurs, t is the time-to-maturity of the contract, d is the dividend yield, D is a dummy variable associated with over and under pricing ($D = 1$ for under-pricing, 0 otherwise), TC is the total trading cost for members, First regression $SS = 1$ for period with no short-selling, 0 otherwise. Second regression $SS = 0$ for final period with the least short-selling restrictions, 1 otherwise. α_s are regression coefficients; η is the error term of the regression model.

sociated with the change in short selling regulations. As expected it is positive and significant because larger pricing errors are expected with more restrictions on short-selling. The removal of short selling restrictions results in a fall in the level of mispricing. The size of the pricing error is positively related to time to maturity and market volatility, a result consistent with that of Yadav and Pope (1994). Pricing errors are also positively related to dividends and to time to maturity consistent with Bhatt and Cakici (1990) and MacKinlay and Ramaswamy (1988).

The results for the 1996 changes largely confirm the results for 1994 for a zero level of transaction costs. Consistent with expectations the coefficient for SS is positive for zero transaction costs around the event date. Once members transactions costs are allowed for the number of mispricing opportunities is so small that further analysis is not meaningful.

Table V reports the results of the regression of Δe against elapsed time lag since observation of mispricing. As predicted, β is negative and significant for all arbitrage signals. The longer the time from the intial mispricing signal being observed, the smaller the profit opportunities that remain. $\Delta\beta$ as expected is not significant for the short-hedge arbitrage signals but is significant for the long-hedge arbitrage signals. The reduc-

TABLE V

Regression Results on the Analysis of the change in Profitability

	Dependent Variable	*N*	*F-stat*	R^2	β	$\Delta\beta$
All Arbitrage signals	Δe	7243	765.508	0.1745	−2.80	−0.174
					(−30.210)[a]	(−1.147)
Short-hedge arbitrage signal (e^+)	Δe	6806	716.896	0.1741	−2.872	−0.084
					(−29.296)[a]	(−0.531)
Long-hedge arbitrage signal (e^-)	Δe	437	83.244	0.2768	−1.746	−2.613
					(−9.711)[a]	(−4.806)[a]

Note: *t*-statistics in parentheses

[a]significant at 1%

Model 2: $\Delta e = \beta L + \Delta\beta L D_t + \varepsilon$

For regression (1) (all arbitrage signals), $\Delta e = P_L^+ - e^+$ if $e > 0$; and $\Delta e = P_L^- - e^-$ if $e < 0$.

For regression (2) (short-hedge arbitrage signal, e^+), $\Delta e = P_L^+ - e^+$; $e > 0$.

For regression (3) (long-hedge arbitrage signal, e^-), $\Delta e = P_L^- - e^-$; $e < 0$.

Δe is the change in the profitability in the arbitrage strategy after a particular time lag L (L ranges from 3 to 15 minutes. The magnitude of the signal (initial profitability) is determined by |e|, and the strategy is determined by the sign of the error. P_L is the (ex-ante) profitability of the strategy determined previously by the sign of the signal (note that P_L can be positive and negative). β is the slope coefficient for period 1, $\Delta\beta$ denotes the change (if any) in the slope coefficient in period 2 relative to period 1. D_t is a dummy variable which distinguishes observations in period 1 from those in period 2. D_t is equal to 0 within period 1, and is equal to 1, otherwise, ε is the error term of the regression model.

tion in the short selling restrictions made shorting the stock easier and improved the speed of reaction of the market to mispricing.

CONCLUSIONS

The analysis of transactions data covering April 1993 to September 1996 provides strong support to the hypothesis that constraints on short selling increase mispricing. Examination of periods of no short selling, partial short selling, and no restrictions on short selling of the index stocks suggest quite clearly that mispricing is reduced as the constraints are relaxed. This conclusion holds for a number of alternative methods of analyzing the data and for transaction costs. Ex-ante tests, which allow time for trading to take place, provide additional confirmatory evidence and reveal that profitable arbitrage is difficult, if not impossible, except for market members with very fast response times.

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