THE DUAL LISTING OF STOCK INDEX FUTURES: ARBITRAGE, SPREAD ARBITRAGE, AND CURRENCY RISK

JOHN BOARD
CHARLES SUTCLIFFE

INTRODUCTION

The first stock index future, the Value Line Composite, began trading on February 24, 1982. Since, the number of index futures has expanded very rapidly and by 1995 over 30 different futures were traded in more than 20 countries. Most index futures are purely domestic (i.e., based on indices containing shares from only that country, with a contract multiplier in the same currency as the underlying shares, and traded in that country). Since 1986, contracts have been introduced which involve an international dimension, in that the underlying asset is not traded in the same country as the futures.

The authors wish to thank the referees of this journal and the participants in a seminar at the University of Southampton for their comments on an earlier version of this article. They also wish to thank the staff of Simex and the CME for supplying background information.

- *John Board is a Reader in Finance in the Department of Accounting and Finance at the London School of Economics and Political Science.*
- *Charles Sutcliffe is a Professor of Finance and Accounting in the Department of Accounting and Management Science at the University of Southampton.*

The Journal of Futures Markets, Vol. 16, No. 1, 29–54 (1996)

CCC 0270-7314/96/010029-26

Most index futures can be traded by anyone, irrespective of their country of residence. New developments, such as the introduction of Globex on June 25, 1992, make it easier for traders based in one country to trade futures listed on a foreign exchange. This raises the question of why futures in a particular index are traded on two or more markets.[1] The no-arbitrage condition for index futures based on the shares of a single country, with a multiplier in the same currency as that of the underlying shares and traded in the same country, has been widely analyzed. (See Sutcliffe, 1993, for a summary.) However, there has been no explicit analysis of futures pricing and risk for cases when these conditions do not apply. The purpose of this article is to fill this gap.

The first section summarizes the history of dual listed index futures, the second contains a derivation of the spot-futures no-arbitrage conditions for dual listed index futures, while the third section considers spread arbitrage between dual listed index futures. The theoretical results derived in the second and third sections are summarized in the fourth, and in the fifth there is an empirical analysis of the Nikkei Stock Average traded in Japan, Singapore, and the USA.

DUAL LISTED INDEX FUTURES

The index futures which have been dual listed or which involve an international dimension are summarized in Table I.

The home country of an index future is defined as the country where the shares underlying the index are traded. A foreign country is one where there is a market in futures on an index whose underlying shares are not traded in that country. The underlying currency is that in which the underlying shares are denominated, while a foreign currency is any other currency. Table II shows the four possible combinations of multiplier currencies for home and foreign countries, together with the contracts traded for each combination. (In addition, the Eurotop 100 is traded on the FTA and denominated in ECUs, the FT–SE Eurotrack 100 was traded on LIFFE and denominated in Deutsche marks, while the FT–SE Mid 250 was traded on two U.K.

[1]There is a considerable literature on the dual listing of equities: see Alexander, Eun, and Janakiramanan, 1987 and 1988; Barclay, Litzenberger, and Warner, 1990; Biddle and Saudagaran, 1989; Chan, Fong, and Stulz, 1994; Diltz and Ting, 1992; Edwards, 1993; Fry, Lee, and Choi, 1994; Garbade and Silber, 1979; Howe and Kelm, 1987; Howe and Madura, 1990; Jayaraman, Shastri, and Tandon, 1993; Kleidon and Werner, 1993; Lau, Diltz, and Apilado, 1994; Lee, 1991, 1992; Makhija and Nachtmann, 1990; Neumark, Tinsley, and Tosini, 1991; Pagano, 1989; Pagano and Röell, 1990; Ripley, 1975; Röell, 1992; Saudagaran, 1988; Stapleton and Subrahmanyam, 1977; Varela and Lee, 1993; and Yagil and Forshner, 1991.

TABLE I
Summary of Dual Listed and International Index Futures

Index	*Exchange*	*Country*	*Multiplier*	*Start Date*	*End Date*
Nikkei[d]	Simex	Singapore	¥500	3rd Sept. 1986	—
	Osaka SE[a]	Japan	¥1,000	3rd Sept. 1988	—
	CME	USA	$5	25th Sept. 1990	—
Nikkei 300	Osaka SE[a]	Japan	¥10,000	14th Feb. 1994	—
	Simex	Singapore	¥10,000	3rd Feb. 1995	—
Topix	Tokyo SE[a]	Japan	¥10,000	3rd Sept. 1988	—
	CBOT	USA	¥5,000	27th Sept. 1990	13th Dec. 1990
FT–SE 100	LIFFE[a]	U.K.	£25	4th May 1984	—
	CME	USA	$50	15th Oct. 1992	—
	OMLX[b]	U.K.	£10 or £25	13th Feb. 1995	—
FT–SE Mid 250	OMLX[a]	U.K.	£10	4th Feb. 1994	13th Feb. 1995
	LIFFE[a]	U.K.	£10	25th Feb. 1994	
	OMLX[b]	U.K.	£10 or £25	1st June 1994	—
OMX[c]	SOM[a]	Sweden	100 SK	3rd April 1987	—
	OMLX	U.K.	100 SK	15th Dec. 1989	—
Eurotop 100	FTA	Netherlands	50 ECU	6th June 1991	—
	Soffex	Switzerland	50 SF	6th June 1991	17th July 1992
	Comex	USA	$100	26th Oct. 1992	—
GEMx	OMLX	U.K.	10 DM	3rd May 1991	25th May 1992
FT–SE Eurotrack 100	LIFFE	U.K.	100 DM	26th June 1991	17th June 1992
MSCI Hong Kong	Simex	Singapore	100 $HK	31st March 1993	—

[a]Home market, Osaka SE = Osaka Securities Exchange, Simex = Singapore International Monetary Exchange, CME = Chicago Mercantile Exchange, Tokyo SE = Tokyo Stock Exchange, CBOT = Chicago Board of Trade, LIFFE = London International Financial Futures and Options Exchange, SOM = Stockholms Optionsmarknad, OMLX = London Securities and Derivatives Exchange, FTA = Financiële Termijnmarkt Amsterdam, Soffex = Swiss Options and Financial Futures Exchange, Comex = Commodity Exchange, New York.
[b]These are the flex futures.
[c]These two markets are electronically linked, and operate as a single market place for OMX futures.
[d]Throughout this article, the Nikkei Stock Average (or Nikkei 225) will be referred to as the Nikkei.

TABLE II
Combinations of Multiplier Currencies for Home and Foreign Countries

Home Country	*Foreign Country*	
	Traded in the Underlying Currency	*Traded in a Foreign Currency*
Not Traded	Nikkei (Simex) until 1988 GEMx (OMLX) MSCI Hong Kong (Simex)	None
Traded in the Underlying Currency	OMX (OMLX) Topic (CBOT) Nikkei (Simex) from 1988 Nikkei 300 (Simex)	Nikkei (CME) FT–SE 100 (CME) Eurotop 100 (Soffex) Eurotop 100 (Comex)

exchanges. Flex futures are traded on two U.K. indices by OMLX, and the corresponding conventional futures are traded on LIFFE).

Even though index futures in different countries may be based on the same index, they usually differ in a number of respects, and therefore, are not perfect substitutes. For example, the countries may be in different time zones. Thus, U.S. investors may trade the Nikkei during U.S. business hours, and Japanese traders may use the Chicago future to react to new information when Osaka is closed. Another benefit of dual listing is that foreign index futures permit a new range of spreading strategies using futures traded on the foreign exchange to be implemented without delay, e.g., a spread between the Nikkei and the S&P 500 in Chicago. Such spreads may also qualify for a reduced initial margin payment if both legs are executed in the same market.

Differences between index futures on the same underlying shares may arise because they differ in their delivery months, margin requirements, contract size, tick size, etc. While these factors might appear to be of minor importance, there is a suggestion from other futures that such differences can be crucial in determining the demand for trading one future rather than another, when both are based on the same underlying asset. One future may be screen-traded (e.g., the Nikkei in Osaka), while another (e.g., the Nikkei in Chicago and Singapore) is traded by open outcry. There may also be differences in transactions costs between the two exchanges. For example, moves by the Japanese regulatory authorities to make trading Nikkei futures in Osaka more difficult by reducing the trading hours, increasing the margins to 30%, reducing the daily price limits and doubling the commission charges led to a very large increase in Nikkei futures volume on Simex in 1992–94 (see Table VII), Quick Research Institute (1993). Similarly, a tax on futures trading, such as that repeatedly proposed in the USA, effectively creates differential transactions costs between exchanges.

In addition, countries operate different regulatory regimes, so the rules on price limits, trading halts, position limits, dual trading, insider trading, etc. differ from country to country. Traders may prefer to use a futures market with which they are familiar and in which they have confidence, rather than the index future's home market. Finally, the multiplier for a foreign index future may be in a currency different from that of the underlying assets. While this means that riskless spot-futures arbitrage is not possible (as will be explained in the next section), it has the advantage that, say, an American investor can obtain exposure to the Japanese stock market without the need to open a foreign currency account or incur any currency risk because all the initial and variation margin payments are in U.S. dollars, not Japanese yen.

SPOT-FUTURES ARBITRAGE

Single Home Market

Initially, an example is given of an index future traded in a foreign country with a multiplier in a currency that differs from that of the underlying shares using the Nikkei Stock Average futures traded on the CME in U.S. dollars. This analysis also applies to the FT–SE 100 traded by the CME. Throughout the derivation of arbitrage conditions in this section and the next, it is assumed that the relevant markets are open simultaneously. This assumption is true for Osaka and Singapore, but not for Osaka and Chicago. The empirical analysis in the fifth section examines this problem.

Table III sets out the cash flows in U.S. dollars for an investor arbitraging the CME Nikkei future, buying shares and selling futures. Since the timing and magnitude of dividend payments on the basket of Japanese shares corresponding to one Nikkei future between now and delivery is assumed to be known, the Japanese dividends in yen can be converted to U.S. dollars using the appropriate forward prices. This enables the computation of $D_0^{\$}$, the present value in U.S. dollars of the dividends received from owning the index basket of shares corresponding to one future between now, time 0, and delivery, time T. Borrowing to finance the purchase of the Japanese shares is assumed to be in U.S. dollars at the U.S. interest rate for the period of the arbitrage, i.e., $r^{\$}$. The initial cost of the index basket of Japanese shares in U.S. dollars

TABLE III
Cash Flows in U.S. Dollars for an Arbitrage Position

	Time	
	0	T
Future (1 contract short)	0	$F_0^{\$} - I_T m^{\$}$
Shares (1 contract long)	$-S_0^{¥}/c_0$	$S_T^{¥}/c_T$
Loan to finance share purchase	$S_0^{¥}/c_0$	$-S_0^{¥}(1 + r^{\$})/c_0$
Dividends received	$D_0^{\$}$	0
Total cash flows	$D_0^{\$}$	$F_0^{\$} - I_T m^{\$} + S_T^{¥}/c_T - S_0^{¥}(l + r^{\$})/c_0$

($S_0^\$$) can be computed using the current spot U.S. dollar–Japanese yen exchange rate, while the current price of Nikkei futures on the CME ($F_0^\$$) is expressed in U.S. dollars. The Nikkei index at time t is denoted by I_t, the dollar contract multiplier in Chicago by $m^\$$, and c_t is the U.S. dollar–Japanese yen exchange rate at time t in Japanese yen per U.S. dollar. The initial cost of the index basket of shares in Japanese yen is $S_0^¥ = S_0^\$ c_0 = I_0 m^\$ c_0$, and the value of these shares at delivery is $S_T^¥ = S_0^¥ I_T/I_0$.

The novelty in Table III is that the long position in Japanese shares is denominated in Japanese yen and not U.S. dollars. Hence the inclusion of the c_t terms in the table to convert the Japanese yen amounts into U.S. dollars. For there to be no arbitrage profit, it is necessary that the present value of the cash flows from the arbitrage transactions contained in Table III be zero. Assuming no transaction costs, it is required that:

$$D_0^\$ + (F_0^\$ - I_T m^\$ + S_T^¥/c_T)/(1 + r^\$) - S_0^¥/c_0 = 0 \qquad (1)$$

Since $S_0^\$ = S_0^¥/c_0$, $S_0^¥ I_T/I_0 = S_T^¥$ and $S_0^¥ = I_0 m^\$ c_0$, this expression can be rearranged to give a new no-arbitrage condition for cases where the index future and the underlying shares are in different currencies:

$$F_0^\$ = (S_0^\$ - D_0^\$)(1 + r^\$) - S_T^¥(1/c_T - 1/c_0) \qquad (2)$$

The first term on the right-hand side of eq. (2) is the usual expression for the spot-futures no-arbitrage futures price (all denominated in dollars), which is

$$F_0 = (S_0 - D_0)(1 + r) \qquad (3)$$

The second term in eq. (2) indicates that, when the shares are denominated in one currency and the index future is in another, an extra term must be included in the spot-futures no-arbitrage condition. This is to allow for the gains or losses on converting the index basket of shares from the currency of the underlying shares (Japanese yen) to the "foreign" currency (U.S. dollars) at the end of the position. If the exchange rate is stable (for example because the two countries are part of a currency block that maintains fixed parities) then $c_0 = c_T$ and this new term disappears.

Using forward or futures markets, it is possible to lock-in an exchange rate for time T, i.e., to set c_T now. Unfortunately, the amount of money involved ($S_T^{¥}$) is uncertain at time 0, so there is currency risk and it is generally not possible to create a riskless arbitrage between the future and the underlying shares. The next section contains a method of virtually riskless arbitrage for such index futures.

Traders who attempt to exploit discrepancies between the spot and foreign futures prices require compensation for bearing the risk of this transaction. Such a trader must also bear the additional transactions costs of converting S_0 into the currency of the underlying shares, and S_T back into the foreign currency. In addition, transactions costs are likely to be higher, and execution slower, for traders based in a country other than that of the underlying shares. This implies that the discrepancies between the spot and futures price for such futures are larger than for the corresponding future in the home country. Thus, the prices of FT–SE 100 futures traded on the CME may be more volatile than FT–SE 100 futures traded on LIFFE. Such an increase in volatility reduces the attractiveness of the foreign index future for hedging purposes.

This analysis of spot-futures arbitrage for index futures with a multiplier and underlying shares denominated in different currencies permits some conclusions about the other possibilities contained in Table II. It reveals that, where an index future is traded abroad, but the multiplier is in the same currency as the underlying shares, $c_0 = c_T$ and the usual spot-futures no-arbitrage condition continues to apply. This result applies to the following index futures: Nikkei (Simex), Nikkei 300 (Simex), OMX (OMLX), GEMx (OMLX), MSCI Hong Kong (Simex), and Topix (CBOT). However, such futures differ from futures traded in the home country, in that the initial and variation margin payments (which are ignored in deriving the spot-futures no-arbitrage condition) must be made in the same currency as the underlying shares. This means that a trader in Nikkei futures on Simex must make and receive margin payments in Japanese yen, not Singapore dollars. Consequently, they must convert money into and out of a foreign currency, exposing their arbitrage profit to currency risk, which may make such spot-futures arbitrage less attractive than otherwise.

The above analysis has a number of implications for arbitrageurs. For a dual listed index future, where both multipliers are in the same currency as the underlying shares, it is likely that spot-futures arbitrage is easier, faster, and slightly cheaper for arbitrageurs based in the home country. Therefore, the spot-futures no-arbitrage band is expected to be smaller in the home country (unless, as in Japan, the costs of trading in the home market are high).

Multiple Home Markets

Some index futures cover shares from a number of countries, and, therefore, have no home market. The FT–SE Eurotrack 100 index includes shares from 13 European countries, and the constituent share prices are converted into Deutsche marks at the spot exchange rate before the computation of the index. This means that the index reflects movements in both share prices and the relevant exchange rates. The underlying assets are effectively denominated in Deutsche marks, and the multiplier of the delisted index future was also in Deutsche marks. Therefore, although this future was traded on LIFFE in the U.K., the usual spot-futures no-arbitrage formula applied, and no currency adjustment was necessary. Margin payments and any profit or loss on this future were in Deutsche marks.

The Eurotop 100 index incorporates shares from nine European countries, and all share prices are converted into ECU at the spot rate before the computation of the index. Thus, as for the FT–SE Eurotrack 100, the usual spot-futures no-arbitrage condition applies to the Eurotop 100 future traded on the FTA, because it has an ECU multiplier. However, the Eurotop 100 was also traded on Soffex with a Swiss franc multiplier, and is still traded on Comex with a U.S. dollar multiplier. Consequently, riskless spot-futures arbitrage of the Soffex and Comex Eurotop 100 futures is not possible because of the currency risk, in the same way that it is impossible for the Nikkei or FT–SE 100 in Chicago.

SPREAD ARBITRAGE

For any underlying asset, it may be profitable to construct a calendar spread between futures contracts with different delivery months if their relative prices are thought to be out of line with the corresponding no-arbitrage prices. However, such calendar spreads are risky and represent speculation on the basis. The existence of two futures on the same underlying index with a common delivery date opens up a new possibility. Spreads between the two index futures can be constructed that result in a riskless arbitrage, e.g., between the Nikkei in Osaka and Singapore. As the two futures have the same delivery date, they must both have the same value of the underlying index at delivery (assuming that the final settlement price is calculated in the same way for both index futures), multiplied by the relevant contract multipliers. Such spreads between dual listed futures will be called *spread arbitrage.*

If the multipliers are both in the same currency, the appropriate spread ratio for use in a spread arbitrage is given by the ratio of the multipliers. For example, the Simex and Osaka Nikkei futures have multipliers of ¥500 and ¥1,000, respectively, so that two Simex futures must be traded for every one Osaka future. If Simex Nikkei futures are underpriced, relative to Osaka Nikkei futures, spread arbitrageurs will sell two Simex futures for every one Osaka future they buy, each for the same delivery date. Letting the contract multipliers in Osaka and Singapore be m^o and m^S, respectively, and F^o, and F^S, be the prices of futures contracts in Osaka and Singapore at time t, the cash flows from such a spread arbitrage are given in Table IV. In this case, the cash flow at delivery is:

$$F_0^o - I_T m^o + (m^o/m^S)(I_T m^S - F_o^S) \tag{4}$$

For the arbitrage profit to be zero, the above expression must equal zero. In which case:

$$F_0^o = (m^o/m^S)F_o^S \tag{5}$$

and the futures prices in Osaka and Singapore are equal, after allowing for the difference in contract size by using the spread ratio (m^o/m^S).

If the multipliers are in different currencies (e.g., the Chicago and Osaka Nikkei futures), an obvious way of judging whether the U.S. dollar and Japanese yen prices of Nikkei futures are in line is simply to convert one of the current futures prices into the other currency (allowing for any difference in contract size via a spread ratio). The spread ratio, allowing for the difference in currencies, is $R = m^{¥}/(m^{\$}c_T)$ Chicago futures for every one Osaka future, and its size depends on the U.S. dollar–Japanese yen exchange rate at delivery (c_T). The cash flows from such a spread arbitrage are shown in Table V. For there to be a zero arbitrage profit from this strategy, it is necessary that, after the U.S. dollar cash flows in Chicago have been converted into Japanese yen:

$$F_0^{¥} = R(F_0^{\$} - I_T m^{\$})c_T + I_T m^{¥} \tag{6}$$

TABLE IV
Cash Flows From a Spread Between Simex and Osaka Nikkei Futures

	Time	
	0	T
Nikkei in Singapore ($m^o/m^S = 2$ contracts short)	0	$(m^o/m^S)(I_T m^S - F_o^S)$
Nikkei in Osaka (1 contract long)	0	$F_0^o - I_T m^o$

TABLE V
Cash Flows From a Spread Between CME and Osaka Nikkei Futures

	Time	
	0	T
Nikkei in Chicago (*R* contracts long)	0	$R(F_0^{\$} - I_T m^{\$})$
Nikkei in Osaka (1 contract short)	0	$I_T m^{\yen} - F_0^{\yen}$

The spread ratio (R), which must be set at time 0, requires a knowledge of c_T. Let $c_T = ec_T^F$, where c_T^F is the forecast of c_T at time 0 and e represents the exchange rate forecasting error. Thus, the spread ratio used becomes $R - em^{\yen}/m^{\$}c_T$. Substituting for R, and using the actual exchange rate at delivery (c_T) to convert the final payoffs in Chicago to yen, eq. (6) can be manipulated to give the ex post mispricing in yen ($M^{\yen}$). This is the actual profit or loss in yen from an arbitrage initiated using the forecast exchange rate at delivery when setting the spread ratio. (Whether $M^{\yen}$ results in a profit or a loss depends on whether the ex ante mispricing computed using the forecast exchange rate ($F_0^{\$}/m^{\$} - F_0^{\yen}/m^{\yen}$), has the same sign as the ex post mispricing. A change in sign indicates a loss.

$$M^{\yen} = (m^{\yen}/m^{\$})F_0^{\$}e - F_0^{\yen} + I_T m^{\yen}(1 - e)$$

Converting to index points by dividing through by $m^{\yen}$ gives the ex post mispricing in index points (M).

$$M = eF_0^{\$}/m^{\$} - F_0^{\yen}/m^{\yen} + I_T(1 - e) \tag{7}$$

If there is no forecasting error and $e = 1$, then eq. (7) becomes

$$F_0^{\yen} = (m^{\yen}/m^{\$})F_0^{\$} \tag{8}$$

which is the same results as in eq. (5) for spread arbitrage between index futures denominated in the same currency. Equation (8) can also be rearranged as $F_0^{\$}/m^{\$} = F_0^{\yen}/m^{\yen}$, which simply states that the current futures price, in index points, is the same in both countries. This result shows that spread arbitrage provides a way of arbitraging foreign index futures; although, if there is a foreign currency multiplier, there is a small amount of currency risk.

Given the much lower costs of trading futures rather than the basket of shares in the index (Sutcliffe, 1993), it is likely that the prices of two index futures will be kept in line through spread arbitrage, rather than by trading the underlying shares. There will also be conventional spot-futures arbitrage between the home index future and the underlying shares. Therefore, the creation of an additional future on an index can lead to an increase in trading volume on other markets where futures on the index are traded, as spread arbitrage brings the prices of these assets into line.

SUMMARY OF THE THEORETICAL RESULTS

The theoretical results derived are summarized in Table VI. In some cells of the table, there are two mechanisms for profiting from the mispricing of a foreign index future. In these cases, spread arbitrage has considerably lower transactions costs than the alternative mechanism, so is likely to be preferred. Where a future is only traded abroad in a foreign currency, riskless arbitrage is impossible. This may explain the lack of any real world examples of this situation.

When the trading hours of the home and foreign markets are such that only one of the futures markets is open, riskless spread arbitrage is not possible. Similarly, if the markets in the underlying shares and the foreign futures are not open simultaneously, riskless spot-futures arbitrage for index futures denominated in the underlying currency is not possible. In these circumstances, the trader must establish one leg of the spread (or spot-futures transaction) in the expectation that the second leg can be entered at an attractive price when the other market opens. This risk implies that price discrepancies must be sufficiently large to cover both transactions costs and a risk premium before spreads or futures-spot positions are opened to exploit such discrepancies.

The derivation of the conventional spot-futures no-arbitrage condition is based on a number of simplifying assumptions [Sutcliffe (1993)]. Two of these assumptions, which are not satisfied by spot-futures arbitrage, are met by spread arbitrage. First, whatever the direction of

TABLE VI
Mechanisms for Profiting from Mispricings[a]

Home Country	*Foreign Country*	
	Traded in the Underlying Currency	*Traded in a Foreign Currency*
Not traded	1. Spot-futures arbitrage (3)	1. Trading spot and futures, subject to currency risk (2)
Traded in the underlying currency	1. Spread arbitrage (5) 2. Spot-futures arbitrage (3)	1. Spread arbitrage (7 or 8) 2. Trading spot and futures, subject to currency risk (2)

[a]The numbers in parentheses refer to the equations containing the particular no-arbitrage condition.

the mispricing, there is no difficulty selling the over-priced asset (as there is in short selling shares), so there is no reason to expect the mispricings to be predominantly in one direction. Second, since both futures positions are marked to market and the positions are of equal and opposite value, the margin payments should, more or less, cancel out. Consequently, there are no net variation margin payments, and the assumption of an absence of such payments is satisfied.

In addition, many of the assumptions which underlie the spot-futures no-arbitrage condition, reviewed at length in Sutcliffe, are unnecessary for spread arbitrage. These assumptions are: dividends are estimated without error, short sale proceeds are paid immediately, the underlying index is arithmetic, no settlement lag for shares, zero value of voting rights, no advantage in investing indirectly in morally questionable shares, costless storage of shares, the nature of the underlying index does not change, borrowing and lending interest rates are equal to the risk free rate, the riskless rate of interest can be forecast accurately, no stale prices in computing the index (Aggarwal and Park, 1994, show that stale prices are a serious problem at the opening of the Nikkei), both assets are tradeable at maturity at the final settlement price, and the value of the index is not determined by the price of the corresponding index future.

One area in which the assumptions underlying spread arbitrage are more restrictive than those underlying spot-futures arbitrage is the assumption of divisibility. Because of the large size of futures contracts, it can be more difficult to match the values of positions in two futures, than in one future and shares. However, if the contract multipliers are in the same currency and one is an exact multiple of the other (e.g., Nikkei in Osaka and Singapore, Topix in Tokyo and Chicago, OMX in Stockholm and London), there is no divisibility problem.

Because spread arbitrage relies on far fewer assumptions than does spot-futures arbitrage, the no-arbitrage condition for spread arbitrage will apply in situations where the spot-futures no-arbitrage condition does not. Excepting differences in transactions costs, this suggests that the no-arbitrage band for spread arbitrage will be tighter than that for spot-futures arbitrage.

EMPIRICAL ANALYSIS OF SPREAD ARBITRAGE

Although there are no previous empirical studies of arbitrage opportunities between index futures, there are some studies for commodities. A study of silver futures traded on both Comex and the CBOT found futures prices on these two exchanges were almost identical [Branch, Gleit, Sooy, and Fitzgerald (1984)]. A similar conclusion was reached by Silber (1981) in a study of CME and Comex gold futures.

Spread arbitrage is investigated here for the two dual listings of index futures with the highest volume—the Nikkei in Singapore and Chicago. (See Table VII.) The Simex Nikkei future represents a dual listing with a multiplier in the same currency as the home market (Japanese yen), while the CME Nikkei future is settled in U.S. dollars, a different currency from that of the underlying asset. Spread arbitrage between Nikkei futures in Osaka and Simex was one of the trading strategies employed by Barings Futures (Singapore). Although Simex is open simultaneously with the Osaka and Tokyo Stock Exchanges (the underlying spot market), at no time is the CME open simultaneously with either the Osaka or the Tokyo Stock Exchanges.

CME, Osaka, and Simex Nikkei futures are traded on the same March, June, September, and December cycle. Trading at Chicago and Singapore is by open outcry, while trading at Osaka is screen-based. The final settlement price of CME and Simex Nikkei futures is the special opening quotation of the Nikkei Stock Average which is used to settle Nikkei futures at the Osaka Securities Exchange, rounded to the nearest one tenth of an index point. The special opening quotation of the Nikkei index is based on the opening prices of the underlying shares on the morning after the futures contract has ceased trading. This procedure permits significant differences between the final settlement price and the closing futures price on the previous afternoon, introducing risk for spot-futures arbitrage but not for spread arbitrage. The last day of trading for Nikkei futures traded at Osaka, Chicago, and Singapore is usually the business day preceding the second Friday of the contract month. The tick sizes are 5, 10, and 5 index points in Chicago, Osaka, and Singapore, respectively.

Opening and closing prices for the near contract are from Datastream between October 10, 1990 and June 30, 1993 for Osaka and Chicago, and between September 5, 1988 and June 30, 1993 for

TABLE VII
Nikkei Stock Average Volume

Exchange	1994	1993	1992	1991	1990	1989
Osaka SE	6,208,821	8,461,458	11,395,469	21,643,085	13,589,049	5,442,647
Simex	5,801,098	4,511,038	2,989,243	721,751	880,513	858,965
CME	548,233	356,523	383,755	246,948	52,046	0

Osaka and Singapore. The prices of Nikkei futures at Osaka, Chicago, and Singapore are stated in index points, so the relevant no-arbitrage condition for futures in the same currency and with the same delivery month is simply that contemporaneous prices are identical. Complicated systems of price limits, whose details can change from month to month, operate in all three markets. Since the price limit rules differ between markets, it is possible that one market is constrained, while the matching price on another market is not, or that they are both constrained, but at different prices. This induces apparent mispricings, which cannot be arbitraged away.

Osaka–Singapore

Osaka trades the Nikkei from 9 AM to 3 PM, while Simex trades this future from 8 AM to 2:15 PM. Since Singapore is one hour behind Japan, the opening prices are synchronous, while the closing prices differ by 15 minutes. Neither Japan nor Singapore operates daylight saving time, so these timings remain constant throughout the year. There is a considerable period of time each day when both the Osaka and Simex exchanges are open simultaneously, and during these periods spread arbitrage is possible. The Simex future on the Nikkei Stock Average has a number of advantages over the Japanese-based trading in Osaka: lower transactions costs, no exchange tax, no suspension of trading for a lunch break, open for 15 minutes longer than Osaka and the ability to trade other futures quoted on Simex [Semkow (1989)].

Based on eq. 5, the proportionate mispricings (d_t) are computed for the opening and closing spreads as:-

$$d_t = (F_t^S/m^S - F_t^o/m^o)/0.5(F_t^S/m^S + F_t^o/m^o) \qquad (9)$$

To enable comparison with the results for Osaka–Chicago spreads (see below), the data is disaggregated into two periods: September 5, 1988, to October 9, 1990, and October 10, 1990, to June 30, 1993. Table VIII contains the means and standard deviations of F_{ot}^o/m^o, F_{ct}^o/m^o, F_{ot}^S/m^S, F_{ct}^S/m^S, and d_t, where the o and c subscripts denote opening and closing prices, respectively. It indicates that, within each of the data periods, the means and standard deviations of the four price series are very similar.

The transactions costs (bid–ask spread, broker's round trip commission, market impact, and the cost of cash balances to meeting margin calls) for spread arbitrage are very small (probably under 0.5%), and although the opening prices are synchronous and the closing prices are

TABLE VIII
Summary Statistics for Osaka and Singapore (5 Sept 1988–9 Oct 1990 and 10 Oct 1990–30 June 1993)

	Mean	*Std. Dev.*	*No. of Obs.*
Index			
Osaka open (88–90)	32430.58	3675.82	518
Osaka close (88–90)	32411.35	3711.33	547
Simex open (88–90)	32438.10	3701.89	510
Simex close (88–90)	32442.93	3711.12	547
Osaka open (90–93)	21221.75	3546.13	668
Osaka close (90–93)	21233.98	3528.18	710
Simex open (90–93)	21170.84	3550.59	647
Simex close (90–93)	21219.62	3605.10	711
Proportionate mispricings			
Osaka open–Simex open (88–90)	0.0822%	0.4815%	496
Osaka close–Simex close (88–90)	0.1007%	0.4520%	547
Osaka open–Simex open (90–93)	0.0150%	0.4874%	647
Osaka close–Simex close (90–93)	0.0677%	0.5177%	710

within 15 minutes, some allowance must also be made for the risk of entering one leg of the arbitrage a short while before the order. For the 1990–93 period, the average percentage mispricing for opening spreads is just 0.015%, or about 3 index points. Since the tick size is 10 index points in Osaka and 5 in Singapore, the average mispricing is about as small as might reasonably be expected.

The mispricings are larger in the 1988–90 period than in the 1990–93 period, and for spreads using opening prices, this difference is statistically significant at the 5% level (see Table IX). This reduction in mispricings over time may be due to a learning effect, because spread arbitrage using index futures first became possible when Osaka introduced the Nikkei future in 1988.

For the opening spreads from 1990 to 1993, the distribution of mispricings is approximately symmetrical, indicating no systematic over or under pricing (see Table X). There are comparatively few large

TABLE IX
Osaka and Simex Mispricings—Comparison of 1988–90 and 1990–93

		z-Statistic	*Probability*	*No. of Obs.*
H_0	$E[d_{ot}^{88-90}] - E[d_{ot}^{90-3}] = 0$	2.32	0.02[a]	496 & 647
H_0	$E[d_{ct}^{88-90}] - E[d_{ct}^{90-3}] = 0$	1.18	0.24	547 & 710

[a]Statistically significant at the 5% level.

TABLE X
Distribution of the Percentage Mispricings (Osaka and Singapore)

	5 Sept 1988–9 Oct 1990		10 Oct 1990–30 June 1993	
Percentage Mispricing	*Osaka Open–Simex Open*	*Osaka Close–Simex Close*	*Osaka Open–Simex Open*	*Osaka Close–Simex Close*
3.5– 4.0	0	0	0	0
3.0– 3.5	0	0	1	0
2.5– 3.0	0	1	0	2
2.0– 2.5	3	0	0	2
1.5– 2.0	1	3	8	6
1.0– 1.5	5	8	7	5
0.5– 1.0	15	12	41	23
0.0– 0.5	158	110	228	213
0.0– 0.0	31	24	34	33
−0.5– 0.0	241	360	267	372
−1.0–−0.5	26	10	49	31
−1.5–−1.0	7	6	7	10
−2.0–−1.5	5	9	2	5
−2.5–−2.0	2	3	1	3
−3.0–−2.5	0	0	0	4
−3.5–−3.0	2	1	2	0
−4.0–−3.5	0	0	0	1
Total	496	547	647	710

mispricings, some of which may be due to the operation of price limits. Using 1.0% as the transactions costs threshold, there are mispricings (after transactions costs) 5.1% of the time. This is considerably smaller than the number of mispricings typically found for spot-futures arbitrage. (For evidence for the Nikkei, see Brenner, Subrahmanyam, and Uno, 1989a, 1989b, 1990a, 1990b; Lim, 1992a, 1992b; and Vila and Bacha, 1994.)

Theory suggests that three of the results for the time series properties of spot-futures mispricings will not hold for spread arbitrage mispricings. First, studies of the deviations from the conventional spot-futures no-arbitrage condition for the S&P 500, FT−SE 100, all Ordinaries and FOX have found that the absolute mispricings for index futures decrease in magnitude and frequency as delivery approaches (Sutcliffe, 1993). However, as shown in Table XI, this was found not to be the case for any of the four spread mispricings considered here. Presumably, this is because there is no decrease in the arbitrage risk caused by dividend and interest rate uncertainty as delivery approaches (as occurs for the spot position in spot-futures arbitrage). Any maturity effects for futures cancel out because they apply to both legs of the spread arbitrage.

TABLE XI
Average Absolute Percentage Mispricings by Weeks to Maturity for Osaka–Simex Spreads

	5 Sept 1988–9 Oct 1990		*10 Oct 1990–30 June 1993*	
Weeks to Maturity	*Osaka Open–Simex Open*	*Osaka Close–Simex Close*	*Osaka Open–Simex Open*	*Osaka Close–Simex Close*
1	0.31%	0.27%	0.35%	0.38%
2	0.42%	0.39%	0.40%	0.36%
3	0.35%	0.28%	0.32%	0.27%
4	0.32%	0.31%	0.33%	0.38%
5	0.28%	0.21%	0.25%	0.21%
6	0.18%	0.36%	0.24%	0.19%
7	0.17%	0.19%	0.29%	0.20%
8	0.24%	0.15%	0.30%	0.28%
9	0.19%	0.17%	0.30%	0.25%
10	0.37%	0.31%	0.36%	0.36%
11	0.21%	0.22%	0.29%	0.30%
12	0.25%	0.19%	0.33%	0.28%
13	0.24%	0.21%	0.25%	0.21%
14	0.24%	0.17%	0.31%	0.41%

Second, significant positive autocorrelation has been found in spot-futures mispricings for index futures (Sutcliffe), including the Nikkei [Brenner, Subrahmanyam, and Uno, 1989a, 1989b, 1990a, 1990b; Lim, 1992a, 1992b; Vila and Bacha, 1994]. While some of these studies used mispricings computed over short intervals (1–60 minutes), others, including Brenner, Subrahmanyam, and Uno (1989a, 1989b), used daily data, and found first order autocorrelations of around 0.8. The first order autocorrelations of Osaka–Simex mispricings for the 1988–90 period are −0.00175 for opening prices and 0.24214 for closing prices, while the corresponding figures for 1990–93 are 0.09914 for opening prices and 0.02888 for closing prices. Therefore, unlike spot-futures mispricings, there is little support for the view that mispricings persist over time (at least from day to day).

Third, early unwinding is profitable when the mispricing reversal is large enough to cover the additional transactions costs of unwinding early, plus the required profit (Sutcliffe). For spot-futures arbitrage, the mispricing reversal may not be large enough to attract fresh arbitrageurs, but is sufficient to cover the very low transactions costs of early unwinding. Such early unwinding tends to prevent the mispricing reversal from becoming larger than the low transactions cost of early unwinding. Consequently, the no-arbitrage band becomes highly asymmetric—the transactions costs for a mispricing in the same direction as the initial mispricing are those of a fresh arbitrageur, while those for a mispricing in the opposite direction to that of the initial mispricing are those for early unwinding (which are much smaller). As a result, spot-futures mispricings (before transactions costs) tend to have the same sign for a given contract. This argument does not apply to spread arbitrage because the costs of early unwinding are the same as those of an initial arbitrage; so the transactions costs remain symmetric and there is no reason to expect the early unwinding option to discourage the mispricing (before transactions costs) from changing sign.

This theoretical prediction, that spread arbitrage mispricings (before transactions costs) for a particular futures contract do not tend to have a common sign, is tested. For each contract, the numbers of positive and negative mispricings are expressed as a percentage of the total number of mispricings for that contract. If the mispricings for a particular contract tend not to change sign, one of these percentages will be large. The average of the largest percentages for the 9 contracts of the 1988–90 period is 60% for opening prices and 71% for closing prices, while the corresponding figures for the 12 contracts of the 1990–93 period are 52% and 59%. While there is some support from the 1988–90 period for the view that mispricings do not change sign, there is no such evidence for the 1990–93 period.

Chicago–Osaka

There is no overlap in trading hours between the Chicago and Osaka exchanges, so that riskless spread arbitrage (and spot-futures arbitrage) is impossible. The chronologically closest prices are the Chicago close and the subsequent Osaka open (2.75 hours later on the following day). The interval between the Osaka close and the Chicago open is 8 hours. In the summer (the first Sunday in April to the last Sunday in October) clocks in Chicago are advanced by one hour. Japan does not have daylight saving time. Consequently, the summer time gaps become 3.75 hours and 7 hours. In addition to the shorter period between the Chicago close and the Osaka open, it is likely that less price sensitive information for the Nikkei is released per hour in the early morning before the Japanese market opens, than in the late afternoon and evening, after the Japanese market has closed [Dravid, Richardson, and Craig (1993)]. This means that price movements from the Chicago close to the Osaka open will be smaller than from the Osaka close to the Chicago open. Dravid, Richardson, and Craig found that CME Nikkei futures are successful in reflecting the relevant information that is released when the Chicago market is open.

Because of the dateline, there is a 50.75-hour gap (51.75 hours in summer) between the Chicago close on Friday night and the Osaka open on Monday morning. Similar increases in the time gap occur for bank holidays. Until January, 1989, the Tokyo Stock Exchange was open for spot trading one Saturday per month. However, the three Nikkei futures have not been traded on Saturdays. Every three months the identity of the near contract changes. When this happens, the Chicago close and the Osaka open relate to different contracts. The Osaka closing price and the Chicago opening price are not subject to the closed market and change of contract problems which affect the Chicago close and the Osaka open.

Chicago futures are denominated in U.S. dollars, while Osaka futures are in Japanese yen; so it is necessary to forecast the exchange rate at delivery when setting the spread ratio. To highlight the effects of forecasting the exchange rate on the arbitrage profit, two cases are analyzed: perfect forecasting ability (i.e., $e = 1$) and forecasts using the current price of a CME dollar–yen future which matures at time $T + 3$ (i.e., three calendar days after the delivery of the Nikkei contract). [The settlement price of Nikkei index futures is usually determined on a Friday, while CME dollar–yen futures cease trading one business day later on the following Monday.] While more complicated forecasting models are possible, this provides a simple procedure using information that is readily available to all potential arbitrageurs.

Based on eq. (8), the proportionate mispricings (x_t) for the difference between the Osaka open and the Chicago close are calculated as:

$$x_t = [F^{¥}_{ot}/m^{¥} - I_T(1 - e) - eF^{\$}_{c(t-1)}/m^{\$}]/0.5(F^{\$}_{c(t-1)}/m^{\$} + F^{¥}_{ot}/m^{¥}) \tag{10}$$

The Chicago open minus the Osaka close proportionate mispricings (y_t) are computed using:

$$y_t = [eF^{\$}_{ot}/m^{\$} - F^{¥}_{ct}/m^{¥} + I_T(1 - e)]/0.5(F^{\$}_{ot}/m^{\$} + F^{¥}_{ct}/m^{¥}) \tag{11}$$

For x_t, mispricings are not computed over weekends or bank holidays, nor are they computed over expiry dates (i.e., using prices for different contracts). As well as the values of x_t and y_t, Table XII contains some summary statistics for the Osaka and Simex prices. Proportionate mispricings with perfect forecasting (i.e., $e = 1$) are denoted, x_t^p and y_t^p, while those which use the price of currency futures are denoted, x_t^f

TABLE XII
Summary Statistics for Osaka and Chicago (10 Oct 1990–30 June 1993)

	Mean	*Std. Dev.*	*No. of Obs.*
Index			
Osaka open	21230.48	3547.11	670
Osaka close	21240.82	3528.06	712
Chicago open	21243.34	3531.64	693
Chicago close	21244.58	3521.26	711
Proportionate mispricings			
Osaka open–Chicago close (x^p)	0.0433%	0.6192%	528
Chicago open–Osaka close (y^p)	0.0260%	0.5790%	693
Osaka open–Chicago close (x^f)	0.1074%	0.6870%	518
Chicago open–Osaka close (y^f)	−0.0396%	0.6418%	679

and y_t^f. This table shows that, over the period studied, the means and standard deviations of the four price series are very similar.

The distribution of the proportionate Osaka–Chicago mispricings is summarized in Table XIII. This shows both the symmetry of the mispricing distributions, and that there are few large mispricings (and these may, in part, be due to the operation of price limits). The predominance of very small mispricings, shown in Table XIII, could be due to the opening price in index points in Chicago (Osaka) being identical to the closing price in Osaka (Chicago). However, this occurs only 7.8% of the time for Chicago open and Osaka close, and 2.5% for Osaka open and Chicago close.

Since the prices for Osaka–Chicago spreads are more widely separated in time than those for Osaka–Simex spreads, there is likely to be more risk from entering one leg of a spread before the other. This implies a larger no-arbitrage band. In addition, the transactions costs of trading Osaka–Chicago spreads must include the currency bid–ask spread and commission. Using a transactions cost threshold of 2% (1%) to allow for this arbitrage risk implies that exploitable opportunities exist only about 2% (7.5%) of the time when $e = 1$, and 2% (10.5%) when e is forecast. With the introduction of currency risk, it is possible that the short and long arbitrage positions should be reversed to give an ex post profit. However, this is a minor problem and occurs in only 2% of cases, reducing arbitrage profits (before transactions costs) by 0.5%.

There is no evidence in Table XIV that the absolute size and frequency of Osaka–Chicago mispricings for $e = 1$, or for the forecast values of e are affected by contract maturity, which is the same result as found for Osaka–Simex spreads.

TABLE XIII
Distribution of the Percentage Mispricings (Osaka and Chicago)

Percentage Mispricing	*Chicago Open–Osaka Close* (y^p)	*Osaka Open–Chicago Close* (x^p)	*Chicago Open–Osaka Close* (y^f)	*Osaka Open–Chicago Close* (x^f)
3.5– 4.0	1	0	1	1
3.0– 3.5	2	3	2	1
2.5– 3.0	1	0	2	2
2.0– 2.5	4	5	3	5
1.5– 2.0	7	2	4	4
1.0– 1.5	14	15	20	28
0.5– 1.0	39	47	47	65
0.0– 0.5	258	192	233	186
0.0– 0.0	54	15	3	0
−0.5–−0.0	249	192	252	161
−1.0–−0.5	44	39	76	48
−1.5–−1.0	12	10	25	9
−2.0–−1.5	5	4	7	4
−2.5–−2.0	2	3	4	2
−3.0–−2.5	1	1	0	2
−3.5–−3.0	0	0	0	0
−4.0–−3.5	0	0	0	0
Total	693	528	679	518

When $e = 1$, the daily Osaka–Chicago spread mispricings for the Nikkei have first order autocorrelation coefficients of 0.126 for the Chicago open less Osaka close mispricings, and 0.145 for the Osaka open less Chicago close mispricings. Thus, there is only slight

TABLE XIV
Average Absolute Percentage Mispricings by Weeks to Maturity for Osaka–Simex Spreads

Weeks to Maturity	*Chicago Open–Osaka Close* (y^p)	*Osaka Open–Chicago Close* (x^p)	*Chicago Open–Osaka Close* (y^f)	*Osaka Open–Chicago Close* (x^f)
1	0.38%	0.30%	0.38%	0.30%
2	0.50%	0.47%	0.51%	0.45%
3	0.35%	0.44%	0.34%	0.43%
4	0.43%	0.58%	0.49%	0.67%
5	0.28%	0.40%	0.39%	0.46%
6	0.21%	0.32%	0.32%	0.41%
7	0.21%	0.34%	0.35%	0.52%
8	0.35%	0.38%	0.45%	0.39%
9	0.29%	0.34%	0.35%	0.39%
10	0.41%	0.50%	0.55%	0.53%
11	0.52%	0.38%	0.47%	0.47%
12	0.28%	0.48%	0.45%	0.59%
13	0.31%	0.34%	0.56%	0.63%
14	0.41%	0.19%	0.68%	0.28%

evidence of persistence in the daily spread mispricings when $e = 1$. For forecast values of e, the corresponding numbers are 0.255 and 0.301, respectively. This indicates that the positive autocorrelation becomes more substantial due to persistence in the errors in the currency forecasts.

A comparison of Tables X and XIII reveals that there are proportionately more large mispricings for Osaka–Chicago than for Osaka–Simex, and that the variances of Osaka–Chicago mispricings are all larger. This is in accordance with the nonsynchronous prices and currency risk for Chicago.

The opening Osaka–Simex mispricing and the Osaka open less the Chicago close mispricing (x_t) both use the opening price on Osaka. If the mispricings in both Chicago and Singapore are caused by the Osaka price being out of line, this would induce positive correlation between synchronous values of these two mispricings for the 1990–93 period. Similarly, the Osaka closing price is used in both the Osaka–Simex closing mispricing and in the Chicago open less the Osaka close mispricing (y_t). Therefore, negative correlation may have been induced.

If the variances of futures prices in Osaka, Singapore, and Chicago are equal (which is supported by the evidence), and if the correlations between the three futures prices used in computing each pair of mispricings are equal, the correlations between the two pairs of mispricings will be 0.5 and −0.5, respectively. The correlations in Table XV between these two pairs of mispricing series for the 1990–93 period are not significantly different from 0.5, or −0.5 (using Fisher's adjustment for a nonzero null, Weatherburn, pp. 200–201.) Thus, problems with the Osaka price can be excluded as a major cause of mispricings.

To investigate whether the possibility of early unwinding discourages the mispricing from changing sign, the percentages of positive, negative, and zero mispricings are calculated for each contract. Across all 12 contracts studied, the average of the largest percentage are 52% for the Chicago open less Osaka close and 55% for the Osaka open less

TABLE XV

Correlations Between Mispricings Which Both Use the Same Osaka Price

	Correlation	*Probability*	*No. of Obs.*
Osaka-Simex open (90–93) and x^p	0.53285	0.71	511
Osaka–Simex close (90–93) and y^p	−0.53280	0.54	692
Osaka-Simex open (90–93) and x^f	0.49391	0.22	501
Osaka—Simex close (90–93) and y^f	−0.48781	0.11	678

Chicago close when $e = 1$, and 68% and 66%, respectively, for forecast values of e. This suggests that there is little persistence in the sign of the mispricing within contracts.

CONCLUSIONS

There have been many tests of the extent to which financial markets in different countries are integrated. This article presents an examination of the integration of index futures markets. It analyzes one aspect of international competition between markets—the trading of what appear to be duplicate products. The dual listing of an index future can lead to an increase in the volume of trading on both exchanges due to the arbitrage activities of market participants. It may also improve market efficiency by increasing the speed with which mispricings are eliminated.

If an index future has a contract multiplier in a currency other than that of the underlying shares, riskless spot-futures arbitrage is impossible. This is because the no-arbitrage condition includes an additional term, which depends on the value of the index basket at delivery, which is uncertain when the arbitrage position is created. If an index future is dual-listed and one of the contract multipliers is in a foreign currency, arbitrage is possible provided an accurate forecast can be made of the exchange rate at delivery. In this case, a simple no-arbitrage condition exists between the two futures contracts, i.e., spread arbitrage. This condition depends on far fewer assumptions than does the spot-futures no-arbitrage condition. If these dual-listed futures are traded simultaneously, the no-arbitrage band between them will be very small due to the low transactions costs of trading futures.

The no-arbitrage condition for dual-listed futures is found to apply to Osaka–Singapore Nikkei spreads, and to Osaka–Chicago Nikkei spreads (despite the time gaps between the trading periods of these markets, and the currency risk). Comparison of the results with and without currency risk supports the view that currency risk is unimportant in spread arbitrage. These findings provide strong evidence that international futures markets are highly integrated. In accordance with theoretical expectations, and in contrast to spot-futures arbitrage, no decline is found in the size and frequency of absolute mispricings from spread arbitrage as delivery approaches. Similarly, there is little first-order autocorrelation in these mispricings, and minimal evidence that early unwinding of spread arbitrage positions prevent the mispricings from changing sign.

BIBLIOGRAPHY

Aggarwal, R., and Park, Y. S. (1994, September): "The Relationship Between Daily U.S. and Japanese Equity Prices: Evidence from Spot Versus Futures Markets," *Journal of Banking and Finance,* 18:757–773.

Alexander, G. J., Eun, C. S., and Janakiramanan, S. (1987, March): "Asset Pricing and Dual Listing on Foreign Capital Markets: A Note," *Journal of Finance,* 42:151–158.

Alexander, G. J., Eun, C. S., and Janakiramanan, S. (1988, June): "International Listings and Stock Returns: Some Empirical Evidence," *Journal of Financial and Quantitative Analysis,* 23:135–151.

Barclay, M. J., Litzenberger, R. H., and Warner, J. B. (1990): "Private Information, Trading Volume and Stock Return Variances," *Review of Financial Studies,* 3:233–253.

Biddle, G. C., and Saudagaran, S. M. (1989, Spring): "The Effects of Financial Disclosure Levels on Firms' Choices Among Alternative Foreign Stock Exchange Listings," *Journal of International Financial Management and Accounting,* 1:55–87.

Branch, B., Gleit, A., Sooy, J., and Fitzgerald, M. (1984): "Contract Proliferation: A Study of the Silver Futures Market," *Rivista Internazionale di Scienze Economiche e Commerciali,* 31:1058–1064.

Brenner, M., Subrahmanyam, M. G., and Uno, J., (1989a, July): "Stock Index Futures Arbitrage in the Japanese Markets," *Japan and the World Economy,* 1:303–330. [Reprinted in (1991): *Japanese Financial Market Research,* Ziemba, W. T., Bailey, W., and Hamao, Y. (eds.), Amsterdam: North-Holland.

Brenner, M., Subrahmanyam, M. G., and Uno, J. (1989b, August): "The Behavior of Prices in the Nikkei Spot and Futures Markets," *Journal of Financial Economics,* 23:363–384.

Brenner, M., Subrahmanyam, M. G., and Uno, J. (1990a): "The Japanese Stock Index Futures Markets: The Early Experience," in *Japanese Capital Markets: Analysis and Characteristics of Equity, Debt and Financial Futures Markets,* Elton, E. J. and Gruber, M. J. (eds.), New York: Harper and Row (Ballinger), 301–334.

Brenner, M., Subrahmanyam, M. G., and Uno, J. (1990b, March–April): "Arbitrage Opportunities in the Japanese Stock and Futures Markets," *Financial Analysis Journal,* 46:14–24. [Reprinted in (1991): *Japanese Financial Market Research,* Ziemba, W. T., Bailey, W., and Hamao, Y. (eds.), Amsterdam: North-Holland.

Chan, K. C., Fong, W. M., and Stulz, R. M. (1994, May): "Information, Trading and Stock Returns: Lessons From Dually-Listed Securities," National Bureau of Economic Research, Working Paper No. 4743, 40 pp.

Diltz, J. D. and Ting, L. S. (1992): "An Empirical Investigation of the Factors That Influence U.S. Firms to Become Inter-Listed on the New York and the Tokyo Stock Exchanges," Working Paper 18–93, School of Accountancy and Business, Nanyang Technological University, 25 pp.

Dravid, A., Richardson, M., and Craig, A. (1993): "Explaining Overnight Variation in Japanese Stock Returns: The Information Content of Derivative Securities," Weiss Centre for International Financial Research, The Wharton School, University of Pennsylvania, Discussion Paper 93–5, 33 pp.

Edwards, F. R. (1993, Winter): "Listing of Foreign Securities on U.S. Exchanges," *Journal of Corporate Finance,* 5:28–36.

Fry, C. L., Lee, I., and Choi, J. J. (1994, March): "The Valuation Effects of Overseas Listings: The Case of the Tokyo Stock Exchange," *Review of Quantitative Finance and Accounting,* 4:79–88.

Garbade, K. D. and Silber, W. L. (1979, August): "Dominant and Satellite Markets: A Study of Dually-Traded Securities," *Review and Economics and Statistics,* 61:455–460.

Howe, J. S., and Kelm, K. (1987, Autumn): "The Stock Price Impacts of Overseas Listings," *Financial Management,* 16:51–56.

Howe, J. S., and Madura, J. (1990, December): "The Impact of International Listings on Risk: Implications for Capital Market Integration," *Journal of Banking and Finance,* 14:1133–1142.

Jayaraman, N., Shastri, K., and Tandon, K. (1993, February): "The Impact of International Cross Listings on Risk and Return: The Evidence from American Depository Receipts," *Journal of Banking and Finance,* 17:91–103.

Kleidon, A. W., and Werner, I. M. (1993): Round-the-Clock Trading: Evidence from U.K. Cross-Listed Securities, National Bureau of Economic Research Working Paper, 41 pp.

Lau, S. T., Diltz, J. D., and Apilado, V. P. (1994, September): "Valuation Effects of International Stock Exchange Listings," *Journal of Banking and Finance,* 18:743–755.

Lee, I. (1991, June): "The Impact of Overseas Listing on Shareholder Wealth: The Case of the London and Toronto Stock Exchanges," *Journal of Business Finance and Accounting,* 18:583–592.

Lee, I. (1992, January): "Dual Listings and Shareholders' Wealth: Evidence from U.K. and Japanese Firms," *Journal of Business Finance and Accounting,* 19:243–252.

Lim, K. G. (1992a, April): "Arbitrage and Price Behavior of the Nikkei Stock Index Futures," *The Journal of Futures Markets* 12:151–161.

Lim, K. G. (1992b): "Speculative, Hedging, and Arbitrage Efficiency of the Nikkei Index Futures," in *Pacific Basin Capital Markets Research,* volume 3, Rhee, S. G. and Chang, R. P. (eds.), Amsterdam: North Holland, 441–461.

Makhija, A. K., and Nachtmann, R. (1990): Variance Effects of Cross-Listing of NYSE Stocks in Tokyo. In *Pacific Basin Capital Markets Research,* edited by Rhee, S. G. and Chang, R. P., Amsterdam: North Holland, 215–226.

Neumark, D., Tinsley, P. A., and Tosini, S. (1991, March): "After-Hours Stock Prices and Post-Crash Hangovers," *Journal of Finance,* 46:159–178.

Pagano, M. (1989, May): "Trading Volume and Asset Liquidity," *Quarterly Journal of Economics,* 104:255–274.

Pagano, M., and Röell, A. (1990, April): "Trading Systems in European Stock Exchanges: Current Performance and Policy Options," *Economic Policy: A European Forum,* 10:63–115.

Ripley, D. M. (1975, June): "Capital Control Policies and Foreign Share Prices," *Journal of Finance,* 30:865–868.

Röell, A. (1992): Comparing the Performance of Stock Exchange Trading Systems. In *The Internationalization of Capital Markets and the Regulatory Response,* Fingleton, J., and Schoenmaker, D. (eds.), London: Graham and Trotman, 167–177.

Quick Research Institute (1993, Autumn): "The Future of Futures in Japan," *Journal of International Securities Markets,* 149–157.

Saudagaran, S. (1988, Spring): "An Empirical Study of Selected Factors Influencing the Decisions to List on Foreign Stock Exchanges," *Journal of International Business Studies,* 19:101–127.

Semkow, B.W. (1989, Winter): "Emergence of Derivative Financial Products Markets in Japan," *Cornell International Law Review,* 22:39–58.

Silber, W.L. (1981, Summer): "Innovation, Competition and New Contract Design in Futures Markets," *The Journal of Futures Markets,* 1:123–155.

Stapleton, R.C., and Subrahmanyam, M.G. (1977, May): "Market Imperfections, Capital Market Equilibrium and Corporate Finance," *Journal of Finance,* 32:307–319.

Sutcliffe, C.M.S. (1993): *Stock Index Futures: Theories and International Evidence,* Chapman and Hall.

Varela, O., and Lee, S.H. (1993, November): "International Listings, the Security Market Line and Capital Market Integration: The Case of U.S. Listings on the London Stock Exchange," *Journal of Business Finance and Accounting,* 20:843–863.

Vila, A.F., and Bacha, O. (1994, September): "Multi-Market Trading and Patterns in Volume and Mispricing: The Case of the Nikkei Stock Index Futures Market," Working Paper, School of Management, Boston University, 42 pp.

Weatherburn, C.E. (1946): *A First Course in Mathematical Statistics,* Cambridge University Press.

Yagil, J., and Forshner, Z. (1991, January): "Gains From International Dual Listings," *Management Science,* 37:114–120.