NEW YORK UNIVERSITY
STERN SCHOOL OF BUSINESS
FINANCE DEPARTMENT

Working Paper Series, 1994

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FD-94-23

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The authors would like to thank Joanne Hill of Goldman Sachs and William T. Ziemba, the editor, for helpful discussions.

ABSTRACT

Stock index futures and program trading are among the most important financial market innovations of the 1980s. This chapter surveys the literature and provides an overview of the somewhat controversial area of index arbitrage. We begin with a description of how index futures work, how they should be priced in equilibrium according to the "cost of carry" model, and how index arbitrage works to enforce the theoretical pricing relationship. In theory, index arbitrage is riskless, but we describe how it is affected in practice by transactions costs, execution risk, capital and short sales constraints, and the possibility of unwinding profitable trades before futures expiration. We end with a discussion of the impact of index futures and arbitrage on the volatility of the underlying stock market.

Program Trading and Stock Index Arbitrage

I. Introduction

The creation of futures contracts based on stock market indexes and the development of program trading are among the most important, and also the most controversial, financial market innovations of the 1980s. On the one hand, index futures are an extremely useful and inexpensive risk management tool that allows an institutional investor to adjust the market risk exposure of an investment portfolio quickly, easily, and cheaply without disturbing the equity holdings in the portfolio. Futures greatly facilitate the management of equity portfolio risk by large scale institutional investors such as pension plan sponsors, first because transactions costs are significantly reduced, but also because they permit decentralized investment decision-making. In which individual portfolio managers are free to invest the funds allocated to them as they choose while overall market exposure is set by a futures overlay strategy that is implemented at the plan sponsor level.

On the other hand, with the ease of trading and the high leverage that these instruments permit, transitory fluctuations in market sentiment can produce powerful effects in the futures market which are then transmitted by arbitrage to the underlying stock market. On numerous occasions during the 1980s, trading in stock index futures was widely blamed as a cause of, or at least a contributor to, turmoil in the stock market, and various constraints were placed on the futures market and on the arbitrage process. The most extreme example, of course, was in the Crash of October 19, 1987 and its aftermath, when the New York Stock Exchange (NYSE) imposed a ban on program trading for several weeks, and a variety of measures to curb index futures trading were introduced thereafter.

In this chapter, we will discuss the instruments, the trading strategies, and to some extent, the controversies surrounding index futures and program trading in stocks.

II. Stock Index Futures Contracts and Program Trading

Index Futures

A futures contract based on a stock index was first proposed by the Kansas City Board of Trade (KCBOT) in 1978. Although the most widely followed stock index in the U.S. is the Dow Jones Industrial Average, the Dow Jones Company opposed the use of their index for futures trading at the time, and continues to do so to this day. The KCBOT therefore proposed a contract based on the Value Line Composite Index, a very broad market index covering about 1700 major stocks. Financial futures were quite new at that time, and to the Commodity Futures Trading Commission (CFTC) which has the responsibility of approving all new futures contracts, the unique design of the proposed contract seemed to pose serious problems. One of the most important was that there was to be no provision for delivery of the underlying stocks.

While few of the contracts outstanding at any one time in a futures market actually result in delivery of the underlying commodity or financial instrument, it is the possibility of delivery that ties the futures price to the cash price at maturity, which is a requirement for effective hedging. However, the stock market is much more active and liquid than the cash market for other futures. There is no difficulty or ambiguity in pricing a broad portfolio of stocks, such as the Standard and Poor's 500 index portfolio, or in calculating the value of an index like the

Value Line.[1] But it would be highly impractical, and in some cases impossible, to deliver the "stock index" itself.[2] In other words, the expiration value of an index futures contract is easily determined by looking at the closing value of the index in the stock market, but the only settlement procedure that makes sense is cash settlement based on price differences. The CFTC was not prepared in 1978 to approve the KCBOT's proposed cash-settled stock index futures contract.

Only in 1982, after the regulatory climate changed under the Reagan Administration, did the CFTC finally allow stock index futures to trade. In that year, the KCBOT won approval for its Value Line contract, the Chicago Mercantile Exchange (CME) introduced the Standard and Poor's 500 (S&P 500) contract, and the New York Stock Exchange opened an affiliated futures exchange. The New York Futures Exchange's (NYFE) primary contract was an index future based on the NYSE composite index.

All three contracts were similar in design. The underlying asset was $500 times the index, with settlement exclusively in cash. Contract months were March, June, September, and December. Like all futures, contracts were guaranteed by the exchange Clearing House, both parties to a trade had to post initial margin, and the margin accounts were marked to market

[1] The original Value Line Index is computed as a geometric average from the returns on the individual component stocks, meaning that there was no actual stock portfolio whose value was represented by the Value Line Index. In 1988, Value Line introduced an arithmetic average index, which was adopted as the underlying index for Value Line futures. The new index measures the value of an equally weighted portfolio of all of the component stocks.

[2] Unlike most stock index futures contracts, the Osaka Stock Futures 50 (OSF50) was settled by physical delivery of the underlying securities. This contract was delisted in 1993 because of the lack of volume since 1988, when the Osaka Securities Exchange introduced the Nikkei Stock Average and the Tokyo Stock Exchange introduced the TOPIX futures contracts.

every day. These procedures essentially eliminated default risk. Also, because the margin procedure prevented a trader from building up large losses on any position that could lead to a default, as in other futures the margin level could be safely set quite low, 5 percent of the value of the stocks underlying the contract or less.

For example, consider a trader who buys December S&P 500 futures on November 1 at a price of 450, and on expiration day in December the S&P index ends at 455. The total return on the long position will be received in the form of a stream of daily margin flows over the holding period, as the contracts are marked to market at each day's futures settlement price. The daily cash payment is $500 per contract times the price change from the previous day. The cumulative value the trader receives over the entire period will be $500 x (455 - 450) = $2500. On expiration day, there is one final payment as all outstanding contracts are marked to the level of the actual S&P index, and then they expire.

Stock index futures were an extraordinary success, with trading volume growing rapidly to many thousands of contracts per day. However, as is frequently found with duplicative futures contracts, one market quickly became dominant and attracted the lion's share of the trading volume, and the others soon became satellites of the primary market. In this case, it was the CME's S&P 500 contract that became dominant.[3]

In time, other index futures were proposed, some of which were introduced, but there were few successes in the U.S. For a time, in the middle 1980s, futures on the Major Market

[3] As of December 27, 1983 the open interest on the S&P 500, NYSE composite and the Value Line futures contracts was 24,576, 11,237 and 3,755, respectively. While, the open interest on the S&P 500, the NYSE composite and the Value Line futures contracts was 117,944, 5,264 and 1,444, respectively, as of December 27, 1988.

Index became active. This index was designed to be very much like the Dow Jones: It is comprised of 20 large stocks, of which nearly all are components of the Dow, and the weighting procedure is the same.[4] Additional support for this contract came from the fact that there was active trading in stock index options based on the same index. Other futures contracts tied to small stocks, such as the Russell 2000, or to different types of indexes were attempted, but so far the S&P 500 is by far the most important index future in the U.S.

In the last few years, stock index futures have been introduced in many countries. Table 1 shows a selection of index futures from around the world. Clearly, index futures are a financial innovation that has widespread appeal.

Index Arbitrage and Program Trading

Unlike stock values, that are determined by expectations of future supply and demand based on earnings and other fundamental economic factors, the equilibrium stock index futures prices are unambiguous and easily calculated. As a derivative instrument, the fair price for an index futures contract is determined completely by the current level of the index in the stock market and the "cost of carry," which depends on the risk free interest rate and the dividend yield. This relation is discussed in the next section.

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[4] Unlike the S&P and most other broad market indexes that weight each component stock in proportion to the total capitalization of the firm ("cap" weighting), a few indexes, including the Dow and the Japanese Nikkei 225 are essentially based on the value of a portfolio containing one share of each stock. This causes the return on a given stock to affect the index in proportion to its price ("price" weighting). The third common weighting procedure for a stock index is equal weighting, in which the percent change in the index is computed as a simple average of the returns on the component stocks. In 1994 the cap weighted Nikkei 300 was introduced in Japan.

This theoretical price relationship is enforced by arbitrage between the cash and futures markets. For example, if the futures price in the market is higher than its theoretical value, an arbitrage opportunity arises in which the overpriced future is sold and the underlying stock index portfolio is bought, to create a riskless position with a high return. Executing that trade involves simultaneously purchasing all of the component stocks in the correct proportions to duplicate the index. Such a trade of an entire portfolio of stocks at once is known as a "program trade." Arbitrage between a stock index future and the underlying index portfolio clearly requires a program trade, but not all program trades are related to index futures. The NYSE defines any simultaneous trade involving 15 or more stocks and a market value of $1 million or more to be a program trade. With this broad definition, by 1992 the NYSE reported that 11.5 percent of total trading volume was program trading. However, in a study of all program trades done on the NYSE during 4 months in 1989, Neal [1993] finds that only 47.5% were related to stock index arbitrage. Other reasons for program trading included liquidation of portfolios (19.8%), portfolio realignment (12.4%), and a variety of other trading strategies.

Effective index arbitrage trading requires the ability to trade the index futures (or options)[5] contracts and quickly execute a program trade of the underlying stocks. For a broad stock market index portfolio like the S&P 500, simultaneously trading all of the component stocks presents a considerable challenge. In the first few years of index futures trading, there were no formal procedures for program trading and arbitrageurs were forced to enter orders

[5] Options based on broad stock indexes are also actively traded, but an options arbitrage is much more complicated than a futures arbitrage because the position must be adjusted dynamically as the market moves. The result is that, as Neal (1993) shows, there is actually little program trading associated with index options arbitrage. We confine our attention in this chapter to arbitrage with stock index futures.

exactly as if each of the stock trades was a separate transaction, a cumbersome process when a large number of stocks were involved. To accelerate execution, they frequently traded surrogate portfolios consisting of a much smaller number of the most liquid stocks in place of the entire index portfolio.

By the middle 1980's, however, trading technology in the U.S. had advanced to the point that it was possible to generate the individual buy or sell orders for exchange-traded stocks by computer and to transmit them electronically through the New York Stock Exchange's Designated Order Turnaround (DOT) system directly to the various exchange trading posts. While trading a surrogate portfolio is still common, it is now possible to buy or sell nearly the entire S&P 500 index portfolio within about 2 minutes and frequently much faster than that. Neal [1993] reports that in 1989, the average number of stocks in the cash leg of an S&P futures arbitrage was 375 (with a standard deviation of 155); the average for an NYSE futures arbitrage was only 292, even though the index contains over 1600 stocks.

The heavy use of computers in the strategy gave rise to a common misconception that the trading decisions in an index arbitrage are made automatically by computer. This is false: the computer's role is essentially the clerical task of generating a large number of orders efficiently and transmitting them electronically into the market. The trading decisions are made by human traders.

Internationally, the nature of program trading and index arbitrage varies considerably from country to country. In Japan and France, like the U.S., portfolio trades may be executed stock by stock electronically throughout the day, while in most other markets (e.g., Germany, Switzerland, the Netherlands) orders have to be carried by hand to the specialists on the trading floor, as they were in the U.S. when index futures trading first began. In the U.K., trading is done by dealers through a screen-based quotation system, like the OTC market in the U.S. The lack of simultaneous execution of the program orders increases execution risk.

III. STOCK INDEX ARBITRAGE IN THEORY

Index Futures Pricing in a Frictionless Market

In futures and stock markets, absent transactions costs and other market frictions, the Law of One Price should hold: securities (and portfolios of securities) with identical cash flows must sell for the same price and opportunities for riskless arbitrage profits should not exist. This principle is the basis of the "cost of carry" pricing relationship for futures contracts.

Consider the strategy of buying the portfolio of stocks that comprise the index at date t and simultaneously selling stock index futures contracts that mature on some later date T. Although there is no way to deliver the stocks to satisfy the short position in the futures market, the futures price at expiration on date T will be set equal to the index level in the stock market at that time, so the futures trade effectively locks in today's futures price as the total amount that will realized on the stock portfolio when the position is unwound at T. We are treating futures as if they were forward contracts, leaving out the second order pricing effects of initial margin and marking to market. More importantly, for the moment, we are ignoring transactions costs.

In other words, if the initial index value and futures price are $P(t)$ and $F(t,T)$, respectively, and their final values on date T (the same for both the index and the expiring future) are $P(T)$, then the stock trade will earn $P(T) - P(t)$ and the short futures position will yield $F(t,T) - P(T)$, so the total return on the combined position (excluding dividends) is $F(t,T) - P(t)$, which is fixed at the outset. Any difference between the index level at which the stock position is liquidated on date T and the initial date t futures price is offset by a matching profit or loss on the futures.

Thus the arbitrage trade creates a fully hedged riskless position for the period from t to T. The total return is equal to the dividends paid by the stocks over the holding period, plus price appreciation equal to the difference between the date t futures price and spot index level. But since this return is riskless, by the Law of One Price it must be the same as the return on other risk free investments, i.e., the riskless rate of interest. This relationship then yields the equilibrium futures price as a function of the level of the spot index, its future dividend payout and the riskless interest rate:

$$F^{e}(t,T) = P(t)\ e^{r\,(T-t)} - \sum_{s=t+1}^{T} D(s)\ e^{r\,(T-s)} \qquad (1)$$

where $F^{e}(t,T)$ is the theoretical date t price of the futures contract maturing at date T, P(t) is the date t value of the cash index underlying the futures contract, r is the riskless interest rate applicable to the period from t to T (expressed as a continuously compounded percent per day), and D(s) is the date s dividend inflow on the stock portfolio, measured in index units and assumed to be known as of t.

This is commonly called the "cost of carry" value, because the futures price is equal to the index at date t plus the net cost of carrying the position until futures expiration (i.e., the riskless interest rate less the dividend payout). Equation (1) takes into account the actual dividends paid by the component stocks and the dates on which they are expected to be paid.

This is the correct to handle dividends, but it can be quite burdensome to try to forecast future dividends and payout dates for a large number of stocks. A broad stock portfolio produces a fairly continuous stream of dividend payments.[6] These can vary considerably from day to day, but no single day's payment is a very large percent of the index. For many purposes, equation (1) can be approximated quite closely by the simpler expression in equation (2):

$$F^{e}(t,T) \approx P(t)\; e^{(r-d)\;(T-t)} \tag{2}$$

where d is the expected dividend yield on the index portfolio over the holding period, expressed at a continuously compounded daily rate.

If the cost of carry relation is not satisfied at every instant t during the futures contract life, then an opportunity exists to make a riskless arbitrage profit equal to the mispricing, that is, the difference between the actual and theoretical futures prices. For example, when the futures price is above the level given in equation (1), a long index arbitrage position should be taken: The stock index portfolio should be purchased and the futures contract should be sold. Exploitation of the mispricing in this way should cause stock prices to be bid up and futures prices down, driving them toward the theoretical alignment.

At expiration, the futures contracts will mature and will be settled in cash. The stock portfolio should be sold simultaneously, so that the futures and cash legs of the trade are unwound at the same price. The end result will be that the total return on the hedged position,

[6] In Japan, dividend payments are concentrated in the months of March, the end of the fiscal year, and in September.

from the price appreciation locked in by the futures plus the dividend flow from the stocks during the holding period, will be greater than the interest rate that could have been earned on the same capital by investing in riskless securities. If the arbitrage position can be financed by borrowing the necessary funds at the riskless interest rate, the trade will produce a "free lunch," i.e., positive profits on no net investment.

Underpriced futures give rise to arbitrage profits from selling (short) the index stocks, investing the proceeds in riskless securities, and going long futures to lock in the effective index level at which the stocks will be repurchased. The interest earned plus the difference between the initial index level (at which the stocks are sold) and the futures price (that fixes where they will be bought back) will exceed the value of the foregone dividends. However, in practice this trade is distinctly harder to execute than the "cash and carry" long arbitrage, as we will discuss in more detail below.

Transactions Costs

In the real world, traders face market "imperfections," particularly transactions costs. In the presence of these costs, a small mispricing in the futures contract will not produce an arbitrage opportunity large enough to offset the cost of putting on a trade to exploit it. There will be a band around the theoretical futures price within which the actual price may float freely without inducing arbitrage.

Transactions costs in this case are of two types.[7] First there are brokerage fees,

[7] The description of the trading environment in this section, including the structure of transactions costs and the institutional features of trade execution, are specific to the U.S. markets.

commissions, and possibly other cash outlays associated with trading, such as stock transfer taxes. These can vary considerably from market to market, and from trader to trader. For example, in the U.S., brokerage commission rates are negotiable. They can depend on the brokerage firm, the identity of the customer and the nature of its business relationship with the broker, the specific trading strategy employed (for example, whether the broker guarantees execution of the program trade at a particular index level, or simply gives its "best efforts" with no guarantee of the outcome), and numerous other aspects of the transaction.

The second element of transactions costs is "market impact," due to the fact that simply executing a trade will tend to push a security's market price away from its previous level. The bid-ask spread is the major source of this market impact, but it also can happen that a large sized trade will push the market price through the previously reported quote.

The reported index value for U.S. indexes is constructed from the prices at which each of the component stocks last traded (not current quotes). Normally there is about the same probability that the most recent trade for a stock will have been at the bid price as at the ask, so the prices in an index like the S&P 500 are on average at about the midpoint between bid and ask (leaving aside the issue of "staleness" of prices for inactively traded stocks).[8] But if an arbitrageur buys the entire index portfolio, all of the stocks will be traded at their current ask prices, causing an immediate, and spurious, jump in the reported index. Similarly, selling the index portfolio will produce an apparent sharp drop in the index. This effect is known as "bid-

[8] For less actively traded stocks, on occasion the last trade will have taken place sufficiently long ago that the price is not even within the current bid-ask spread. In that case, an index program trade may produce a transaction at a price that is quite far from the reported price for that stock.

ask bounce." In essence, the index itself has a bid-ask spread. The bounce from the center of the market to either the bid or the ask amounts to about 0.5 percent for the S&P 500, according to Sofianos (1993).

If we denote the bid-ask bounce (i.e., the combined effect for both the stocks and the futures) as B and the commissions and other expenses (for a round trip trade) as C, the arbitrage bounds on the actual futures price in the market become[9]

$$F^e(t,T) - B - C \leq F(t,T) \leq F^e(t,T) + B + C \qquad (3)$$

Equation (3) incorporates the fact that when the arbitrage position is held until expiration it will be unwound at the same settlement level for the future and the index, which eliminates the bid-ask bounce.[10] Thus the total transactions cost will involve paying commissions for both entering and unwinding the trade, but only one market impact.

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[9] For exactitude, B and C should be expressed in terms of date T future values. That is, B is the date t bid-ask bounce multiplied by $e^{r(T-t)}$, and all cash payouts for commissions and other trading expenses should be increased at rate r from the date of payout to T.

[10] Unwinding the cash leg of the arbitrage at the precise index level that determines the final settlement of the futures is not necessarily easy. In the U.S., however, this can be done by trading the stocks using "market on close" or "market on open" orders for contracts expiring at the close or open, respectively, of the stock market on expiration day. In the case of the S&P 500 contract, the arbitrageur liquidates the cash position at opening prices, which are also the prices that determine the futures settlement value. Prior to June 1987, the S&P futures contract settled at the close. As we will discuss in more detail below, program trading on the quarterly expirations of stock index futures, stock index options, and stock options, referred to as the triple witching hour, can produce price movements in the stock market. The expiration procedures were changed from the close to the opening to reduce the expiration effects on prices. See Stoll and Whaley (1986, 1987, 1990) and Stoll (1988) for a discussion of the expiration-day effects of stock index arbitrage. Market on close or open orders are not possible in every stock market (e.g., the U.K.), which means that market impact must be considered both at the beginning and at the end of an arbitrage.

Constraints on Capital and Early Unwinding of Positions

Equation (3) specifies a price range around the theoretical futures price, and as long as the market price falls within this band, the mispricing can not be risklessly arbitraged away. The width of the no-arbitrage region depends on commissions plus market impact costs of initiating the trade. However, assuming perfect markets except for transactions costs, as soon as the price bound is breached, arbitrageurs should be willing to take essentially unlimited positions. This would effectively turn the Equation (3) bounds into reflecting barriers for the futures price.

In practice, unlimited arbitrage does not happen, for several reasons. One is that as prices move over time, the opportunity to unwind a trade profitably before expiration may arise. This possibility affects the decision on where to get into an arbitrage position: An aggressive arbitrageur may put on a trade inside the equation (3) bounds in the hopes of being able to realize a profit by unwinding early. On the other hand, real world constraints on capital and other limitations, like exchange-imposed position limits, prevent arbitrageurs from taking infinitely large positions regardless of profit possibilities. In the face of strong market pressures, limited arbitrage trading may not be sufficient to keep the futures price within the no-arbitrage range. Finally, execution risk and other uncertainties (about the amounts and timing of future dividends, for example), along with the existence of a wide range of effective transactions cost structures within the population of potential arbitrageurs can blur the exact location of the price bounds considerably.

The effects of early unwinding and capital constraints on the equilibrium range for index futures prices have been analyzed theoretically by several authors, including Merrick (1989) and Brennan and Schwartz (1990). If an index arbitrage position is not held until expiration of the futures contract, a second market impact cost will be incurred in closing it. However, if the initial futures mispricing that generated the trade is reversed and futures become mispriced in the other direction by an amount large enough to cover the additional market impact cost, it is rational to unwind the position early, before expiration. In practice, index arbitrageurs may enter and exit arbitrage positions on both sides of the market in the same contract many times within a contract cycle. It is also possible, as Merrick points out, to extend the holding period past the expiration of one futures contract by rolling the futures component of the trade forward into the next expiration month without liquidating the cash position. Rolling forward at a favorable spread in the futures prices can enhance the arbitrage profit.

Since real world arbitrageurs are constrained by limited capital from taking infinitely large positions, more flexible unwinding of their trades can substantially raise the realized annual arbitrage returns above those guaranteed by the hold-to-expiration investment strategy. These trades are not riskless, however, because the arbitrageurs' profits are now dependent on the path taken by futures prices. In general, traders must wait and hope that the initial mispricing is eliminated, and then reversed by a large enough amount that they can recover all transactions costs. Still, as Merrick recognized, this possibility can lead arbitrageurs to take positions even when prices are within the transactions cost bounds.

The aggressive risky arbitrage strategy just described is more than a hypothetical possibility: Sofianos [1993] reports that by 1989, nearly 70 percent of S&P 500 index arbitrage trades were unwound prior to expiration, with the average turnaround time being about 24 hours. The average arbitrage trade in his sample was put on when prices were inside the arbitrage bounds, i.e., when the mispricing was not large enough to produce a net profit on a trade that had to be carried to expiration and unwound at fair value.

Brennan and Schwartz (1990) modeled stock index arbitrage activity taking into account the fact that limited capital imposes a constraint on the maximum position an arbitrageur can assume. They assumed a strict limit on the position that could be taken and modeled mispricing as following a Brownian Bridge process. Under these assumptions, they then used option theory to analyze the arbitrage decision. By putting on a position, the trader acquires the option of unwinding it early, while by unwinding, she releases her capital and obtains the option to enter into another trade.

Relaxing the strict position limit assumption made by Brennan and Schwartz, Tuckman and Vila (1992) model the effect of holding costs on arbitrage strategies. Holding costs whose magnitudes depend on the (uncertain) duration of the trade, such as the loss of interest when the investor does not obtain the use of short sale proceeds, can transform riskless arbitrage opportunities into risky investments. Tuckman and Vila derive the partial differential equation governing a risk-averse arbitrageur's optimal dynamic strategy given holding costs and an exogenous mispricing process. It is shown that 1) arbitrageurs will not hold a position unless the potential gains are large enough, 2) they do not trade unlimited amounts, and 3) they may take a position even with an instantaneously negative expected return since any such losses will be accompanied by greater arbitrage opportunities.

Like Brennan and Schwartz, Tuckman and Vila (1992) make the assumption that the mispricing process is exogenous, and not affected by trading. However, this is inconsistent with the empirical evidence reported by MacKinlay and Ramaswamy (1988). They found that the opportunity to put on arbitrage positions on one side of the market affected subsequent price movements. For example, if overpricing in the futures market leads arbitrageurs to put on long stock-short futures positions, they will unwind them if futures become underpriced in a following period, which will tend to support the futures market, relative to the situation with no preexisting arbitrage positions. Thus the mispricing process is path dependent.

More recently, in Tuckman and Vila (1993) the independence assumption was relaxed by allowing the activity of arbitrageurs to feed back into the mispricing process. In that case, 1) arbitrageurs reduce but do not eliminate mispricings; 2) equilibrium prices are kept inside the riskless arbitrage bounds because arbitrageurs take risky positions even when no riskless profit opportunities are available; 3) arbitrageurs are most effective in eliminating mispricings that are transient and conditionally volatile; 4) it is more difficult to eliminate mispricings of long-term contracts because costs increase with the holding period; and 5) arbitrage activity lowers the conditional volatility of the mispricing process. These results are consistent with the empirical evidence that violations of the cost of carry relation still exist and the level of mispricing is positively related to time until maturity.

Constraints on Short Sales

We have alluded to constraints on short selling as impediments to index arbitrage. In the U.S., the stock exchanges do not permit a short sale on a downtick. That is, a stock can not be sold short if it has just dropped in price. The trader must wait until the price ticks up. This introduces a considerable asymmetry between the ease, speed, and risk of executing the arbitrage trade when futures are underpriced versus being overpriced. As we will discuss in the next section, in the early years of index futures trading in the U.S., it was common to observe futures prices falling well below fair value, without much arbitrage trading to offset the mispricing. The difficulty of executing the necessary short sale of the stock index portfolio was a prime explanation. This underpricing of futures contracts still exists frequently for indices heavily weighted by small stocks, such as Value Line.

As one expects in a largely efficient financial market, however, the unexploited arbitrage opportunities such underpricing created were not allowed to persist for very long. Since there is no prohibition on selling stocks on a downtick if the investor already owns them, the many large institutions ("indexers") that follow a basically passive investment strategy of holding the index portfolio were in an excellent position to exploit their natural advantage in doing index arbitrage from the short side.

Within a few years, the indexers had become so adept at the arbitrage trade of buying futures when they were underpriced, selling the index stocks out of their portfolios, and investing the proceeds in Treasury bills (thus risklessly enhancing returns on a passive index strategy) that opportunities on either side of the market had become sparse, small, and risky. It was said that index arbitrage had become a "commodity business," meaning that it did not require any special expertise, the brokerage firms priced their services very aggressively, and profit rates were fairly limited all around.

IV. EMPIRICAL EVIDENCE ON INDEX FUTURES PRICING

Many studies since the introduction of index futures contracts in the early 1980s have reported significant and persistent deviations of futures prices from fair values. The market frictions mentioned in the previous section which make risk free arbitrage difficult, including transactions costs, the uptick rule for short sales in the stock market, the limited supply of arbitrage capital and position limits in the futures market may provide most of the explanation for these results. Table 2 provides a capsule summary of a number of empirical studies of index futures pricing.

The cost of carry model for the pricing of index futures contracts has been the basis of many empirical studies. A common finding is that cost of carry pricing does not always hold exactly in actual markets. Stoll and Whaley (1986) report many violations of the arbitrage bounds in excess of transactions costs during the period April 1982 through December 1985. In fact, for the June 1982 contract, the bounds were violated nearly 80 percent of the time, but for later contracts the rate of violation fell to less than 15 percent. MacKinlay and Ramaswamy (1988) found that the S&P 500 futures contracts expiring in September 1983 through June 1987 violated the cost of carry relation on average 14.4 percent of the time.

In the earliest period of index futures trading, from June 1982 to December 1982, index contracts systematically sold at large discounts to their theoretical values. Modest and Sundaresan (1983), Cornell and French (1983 a,b) and Figlewski (1984 a,b), among others, considered possible explanations for this discount. A primary issue was whether the discounts indicated large foregone arbitrage opportunities (in which case the market would have been highly inefficient), or were simply a result of market frictions that were not in the basic cost of carry formula. Or perhaps they reflected additional factors that needed to be taken into account in determining the equilibrium futures price. No academic seriously asserted gross market inefficiency. But no single explanation for the discounts became widely accepted at the time.

Modest and Sundaresan (1983) examined the June and December 1982 futures contracts on the S&P500 index to determine whether the discount could be explained by the fact that investors do not normally get full use of the proceeds from short sales of stock, so the true cost of shorting the index should include foregone interest on at least a portion of the proceeds. They found that if the proceeds of selling short the stock index portfolio could be fully invested, future prices regularly violated the transactions cost bounds, creating sizable arbitrage opportunities. But when investors could use no more than half of the short sale proceeds, actual futures prices almost always fell within the (expanded) no-arbitrage bounds.

The difference between the tax treatment of futures and the underlying stocks is another factor that could affect equilibrium futures pricing. For tax purposes, all profits and losses on futures are treated as if they were realized by the end of the year, whereas in stocks, capital gains taxes are not levied until the shares are sold. As a result, stockholders have a "tax timing option"[11] that is unavailable to futures traders. Cornell and French (1983 a,b) examined whether this tax difference could explain the discount in futures prices. They showed that the tax timing option does reduce the theoretical futures prices, but did not relate the possible magnitude of the effect to the size of futures mispricing in the market.

These studies tried to explain the mispricing in terms of institutional factors that were excluded in the formula for the fair futures price in equilibrium. By contrast, Figlewski (1984a,b)

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[11] See Constantinides (1983) for a discussion of the concept of a tax timing option.

hypothesized that the discount represented a situation of informational and institutional disequilibrium. As a result, he suggested that the discount was largely the result of unfamiliarity with the new markets and a scarcity of sophisticated arbitrageurs ready to implement the arbitrage trade efficiently. In that case, the mispricing would prove to be a transitory phenomenon. Figlewski (1984a) showed empirically that the futures discount had been decreasing over time for the period June 1, 1982 - September 30, 1983.

More recently, MacKinlay and Ramaswamy (1988) used transactions data on S&P 500 index futures prices and the underlying index from September 1983 to June 1987 to examine the intraday behavior of the deviations of futures prices from fair values. Over this period, the mispricing was positive on average, although it was negative for some contracts. They also analyzed the level and the change in mispricing across time and found that the absolute value of the mispricing was positively related to the time until futures maturity. This is consistent with their hypothesis that, in addition to transactions costs, the no-arbitrage boundaries are affected by other factors that depend on the length of the holding period, such as uncertainty about dividends and future mark to market cash flows, and also risk in tracking the stock index with a partial basket of stocks. As a result, larger mispricing may be permitted to develop at longer times to maturity before arbitrageurs will take a position.

As mentioned above, MacKinlay and Ramaswamy also found the mispricing series to be path-dependent. In particular, conditional on the mispricing having crossed one arbitrage bound, it was less likely to cross the opposite bound. This is because arbitrageurs will close out positions established when the mispricing was outside one bound before it reaches the other bound, thus tending to keep the futures price within the no-arbitrage range.

The discount found during the early period of index futures trading is not unique to U.S. futures markets. Persistent underpricing relative to the cost of carry theoretical value in the early years of trading has been documented in other markets, including Japan and the U.K.

Brenner, Subrahmanyam and Uno (1989 a,b,c) examined the mispricing of the Nikkei 225 Stock Average (NSA) futures contract, traded on the Singapore International Monetary Exchange (SIMEX), and the Osaka Stock Futures 50 (OSF50) futures contract, traded on the Osaka Securities Exchange (OSE),[12] from September 1987 through June 1988. The NSA contract started trading on September 3, 1986 and the OSF50 was introduced on June 9, 1987. The NSA contract is based on an arithmetic average of the prices of 225 stocks traded on the First Section of the Tokyo Stock Exchange (TSE). The spot index for the OSF50 was also an arithmetic price average, but of 50 stocks traded both on the OSE and the TSE. Unlike most stock index futures contracts, the OSF50 contract was settled by physical delivery of the underlying securities during the sample period. This contract was delisted in 1993 because of the lack of trading since 1988 (see footnote 2).

For the NSA contract, the mispricing was predominately negative over the early trading period and the mispricing tended to persist. However, for the OSF50 contract, positive deviations were more frequent. The deviations for the NSA contract were significantly larger than for the OSF50 contract. Over the entire sample period, the mean absolute deviation was 1.22 percent for the NSA contract versus 0.92 percent for the OSF50 contract.

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[12] Bacha and Fremault Vila (1993) examined the mispricing and volume of the NSA futures contract in three different markets (SIMEX, OSE and CME).

More recently, Chung, Kang and Rhee (1994), examined the impact of the Japanese stock market microstructure on the pricing of NSA futures contracts in Osaka using intraday transactions data for the period from September 9, 1988 to September 12, 1991.[13] They found that the NSA futures prices on the OSE have tended to deviate on average 0.41% from theoretical no-arbitrage prices with transaction costs; the contract is predominantly overpriced which is opposite to the results reported by Brenner, Subrahmanyam and Uno (1989 a,b,c) for the SIMEX NSA futures contract during an earlier period; mispricing signals tend to be clustered and persistant; and, the size and frequency of mispricings is positively correlated with the remaining life of the contract.

Yadav and Pope (1990) examined the mispricing of the LIFFE FTSE-100 futures prices over the period July 1, 1984 to June 30, 1988. Their results are very similar to those found for the U.S. futures contracts and the Japanese NSA contract. In addition, like MacKinlay and Ramaswamy they found that the amount of mispricing was positively related to time until expiration.

The previous research utilized the cost of carry model in a static setting, but Brennan and Schwartz (1990) modeled the mispricing as a Brownian Bridge process. We discussed above how they showed that trading costs and position limits in the stock index futures market can make it valuable to close a position before maturity, and therefore it may be worthwhile to open a position even when the costs of opening it plus the costs of closing it at maturity exceed the level of mispricing. The study also included empirical results to support their arguments: the average

[13] In Japan, some of the impediments to arbitrage trading include: high transaction costs, cash margin requirements, relatively long execution lags in the spot market and difficulties in taking short sale positions.

arbitrage profit including the option value was 0.54 index points.

Merrick (1989) also recognized opportunities to reverse arbitrage positions and/or roll positions into the next contract prior to the expiring contract's expiration. He found that early unwindings and rollovers were valuable. Early unwinding profits represented 34% of total profits.

In practice, investors are unable to execute their trades at the instant at which the mispricing occurs, as was assumed by all of the above studies. Habeeb, Hill and Rzad (1991) relaxed this assumption and assumed a five minute execution lag in their analysis of S&P 500 index arbitrage. They also incorporated various trading costs and allowed for unwinding the trade prior to expiration. The study covers the period December 21, 1987 through June 15, 1990. They found that the periods with the greatest range of mispricing were in 1988 and the first half of 1990. The excess return from one-sided long or short arbitrage was about three percent per year while it was as much as 5 percent per year when both long and short positions could be taken.

To this point, all of the studies examined only cash and futures prices and simulated the arbitrage trades. Sofianos (1993) was the first to examine actual S&P 500 index arbitrage transactions obtained from the daily program trading reports of NYSE member firms. He estimated the expected return to expiration and the early-closing return for actual S&P 500 index arbitrage transactions over the period January 15 to July 13, 1990. He found that the average annualized expected return to expiration at the initiation of actual S&P 500 index arbitrage positions over this period was 0.5 percentage points <u>below</u> the opportunity cost of funds. Most index arbitrage positions were established when the mispricing would not cover transactions costs if the position had to be held to expiration.[14] But in practice, the majority of the trades were unwound early, following profitable mispricing reversals. These results suggest that the early close-out option described by Brennan and Schwartz is valuable in practice. In fact, the estimate of the average annualized early close-out return ranged from 0.1 to 4.9 percentage points above the opportunity cost of funds.

V. PROGRAM TRADING AND VOLATILITY

The largest objection to trading in stock index futures has been due to the perception, and fear, that index futures trading and index arbitrage creates excessive volatility in the stock market. The behavior of the index futures market during the 1987 stock market Crash and the well-known and extensive use of stock index futures in "portfolio insurance" strategies at the time produced some of the most extreme concerns and criticisms along these lines, but similar concerns had been voiced earlier, and continue to be heard today.

The Triple Witching Hour

An early indication that index futures trading could have a disruptive effect on the underlying stock market was that stock prices were sometimes observed to behave very peculiarly at the time of the quarterly expirations of index futures and other equity derivatives. Specifically, on expiration day the stock market would occasionally experience an unexplained wave of buy or sell orders in the last few minutes of trading, that would take traders by surprise and drive prices sharply up or down. Large swings in traders' profits and losses could occur in seconds;

[14] In fact, these were risky positions, not arbitrage positions.

options that appeared to be well out-of-the-money with only minutes to go before they expired could suddenly turn into major losses for unwary writers; and generally strange and frightening occurrences seemed possible.

Because these events were unusual and unexplained, and they seemed to be associated with the simultaneous expiration of four kinds of equity derivatives, stock index futures, stock index options, stock index futures options, and some options on individual stocks, the period just before the close of trading on the quarterly expiration date came to be known as the "Triple Witching Hour."[15]

The explanation for the Triple Witching Hour events is actually not hard to understand. They <u>are</u> a result of the expiration of stock index contracts, primarily the index futures, and are produced by the unwinding of index arbitrage trades, as we have described above. Consider an arbitrageur who arrives at the futures expiration date holding a long position in the S&P 500 stocks and a short position in S&P futures contracts. The futures will mature at the close of trading, at which point they will be marked to market at the closing level of the S&P index. In order to unwind the arbitrage position without paying a second market impact and also bearing execution risk, the trader will try to liquidate the position by selling the stocks simultaneously with expiration of the futures contracts, at the market's close. This can even be done with "market on close" orders that lie dormant until the last minute of trading, at which point they become market orders and are executed at whatever the prevailing market price is. Even if this style of trading at the last second were to push the prices received on the stocks down sharply,

[15] See Stoll and Whaley (1986,1987,1990) and Stoll (1988) for an excellent analysis of the expiration day effects of stock index arbitrage.

there would be additional profits on the not-yet-expired short futures position that would offset the losses.

A priori, one might expect that the arbitrage positions that remain to be unwound at futures expiration would be fairly balanced between the long and the short side, so that unwinding them simultaneously at the close would produce largely offsetting trades in the underlying stocks. This often was not the case. In some periods, the arbitrage opportunities tended to lie all on one side of the market, with little or no chance of unwinding the positions profitably before expiration. It was on those occasions that the Triple Witching Hour trades, nearly all in the same direction, could produce sharp market moves.

For example, in early September 1986 the stock market experienced a sharp two-day sell-off. Although it's magnitude, about 120 points on the Dow Jones average, is small in comparison to the October 1987 Crash, at the time, it was the largest market drop since 1929 and it made a large impression on the market. For many weeks afterwards, stock index futures traded well below fair value, which allowed large short stocks-long futures arbitrage positions to be established with the December futures contract.

Since futures remained underpriced throughout the quarter, the arbitrageurs were unable to unwind these positions profitably before expiration. Thus, when they were unwound at the Triple Witching Hour on December 19, 1986, over 85 million shares (more than one third of the entire day's volume) were purchased in the last minute of trading, with the result that stock prices surged upwards.

In 1987, to ease the pressure the Witching Hour caused for stock exchange specialists and others, the expiration procedure was changed for S&P 500 futures. Starting with the June 1987 expiration, final settlement is based on stock prices at the opening on the expiration Friday. The opening procedure on the NYSE is better suited to managing order imbalances, so there is less price disruption when large arbitrage positions are unwound. Other index related contracts did not change their expiration procedures, with the result that the Triple Witching Hour price effects are now effectively spread out over the day.

The Debate on Program Trading After October 1987

Following October 1987, futures trading and index arbitrage were thoroughly examined in a variety of studies sponsored by government authorities, the exchanges, and others. Although they produced a large amount of discussion and statistical evidence, these studies did not produce widespread agreement on the principle issues. Nevertheless, several formal changes to the way index futures are traded were imposed in the aftermath of the Crash. As mentioned above, immediately after the Crash the NYSE banned the use of the DOT system for arbitrage trades for several weeks. This had the effect of disconnecting the index futures aftermath of the Crash. As mentioned above, immediately actions from theoretical pricing to develop and persist.[16]

[16] One result was that arbitrageurs who did succeed in putting on short stocks-long futures positions after the Crash ended up unwinding them on expiration day. As in 1986, the Triple Witching Hour (or Day) in December 1987 produced a sharp rise in stock prices, 50.90 index points in the Dow index for the day.

Margin requirements on index futures were also raised significantly. Prior to October 1987, margins were comparable in size to those for other futures, typically less than 5 percent of the nominal value of the futures contract. For example, if the S&P 500 index were at a level of 400, the value of the stock underlying an S&P futures contract would be $500 x 400 = $200,000. Before 1987, the initial margin requirement on the contract might have been less than $5000. It must be emphasized that "margin" in a futures market is qualitatively different from margin on a stock purchase, which represents a partial payment for securities that are transferred immediately. The futures margin is essentially a performance bond on a contract that only binds the parties to make a transaction at a later date. The purpose of the futures margin deposit is to guarantee that both counterparties will be able to cover any (paper) losses on their commitments prior to maturity.

Given the daily mark to market that keeps the actual margin deposits current as the market prices move, these low margin levels were adequate for the purpose of assuring the financial integrity of the futures contracts. But in comparison to the 50 percent margin required for a stock transaction, futures margins permitted a much greater degree of leverage. Many cash market participants worried that low margins led to speculative excesses in index futures, which then spilled over into the stock through stock index arbitrage trading and produced high volatility there. While calls for government regulation of index futures margins after the crash were not satisfied, the futures exchanges themselves elected to raise stock margin requirements sharply--not to 50 percent, but to the 10 to 15 percent range. In March 1994, following several years of unusually low volatility, the S&P 500 index was at about 450, which translates to a futures contract representing about $225,000 worth of stock, and the initial margin requirement was

$9000, about 4%.

In addition to higher margins following the Crash, the exchanges established a system of "circuit breakers," designed to stop or slow trading, and specifically index arbitrage, in periods of high market volatility. Several different forms of circuit breakers were tried. The current system, which has been in place for a number of years, calls for suspension of futures trading for one half hour if the Dow Jones index falls by 50 points or more in a day; longer trading halts after further market drops; and the "sidecar" which shunts aside program trades in the DOT system and delays their execution for 5 minutes once the SP500 futures contract declines 12 points from the previous day's close.

Academic economists tend to differ sharply with other public commentators on the merits of the basic arguments about index arbitrage and market volatility, as well as about proposed procedures to deal with the problem.[17] A full analysis of the issues is beyond the scope of this chapter, so we will only mention some of the points of debate.

Opponents of futures argue that they facilitate destabilizing speculation that pushes the futures price out of line with the true value of the underlying stocks. Index arbitrage then transmits the price disruption into the stock market. In this way, it is claimed, index futures and arbitrage activity significantly increase volatility and are detrimental to the stock market. The appropriate policy is therefore to restrain index futures arbitrage, especially during volatile market conditions.

[17] See Miller (1993) for a discussion of the politics of index arbitrage in the U.S. and in Japan.

Academic research has produced counterarguments to nearly all of these assertions. First, there is disagreement about whether speculation by futures traders is, or can be, destabilizing to the underlying cash market, a question that has been studied at great length by economists without reaching a consensus. However, it is a mistake to draw a large distinction between stock index futures traders and investors in stocks. As pointed out in the Brady Commission report (1988) that analyzed the 1987 Crash, it is more appropriate to consider the markets for stocks and all of the derivative instruments based on stocks as being different components of a single integrated equity market. Futures trading is done by essentially the same large investors whose activities cause price changes in the cash market. Moreover, the nature of arbitrage trading is that it pushes prices down in one part of the unified stock market, but simultaneously raises prices in another. The resulting change in relative values should not cause any net change in the overall level of stock prices, properly defined.

Second, it is not clear that stock price volatility is actually greater now than before index futures existed, or even that higher volatility would necessarily be undesirable. Mathematically, volatility is the annualized standard deviation of stock returns. This has been found to vary considerably from year to year. It also depends on the time interval between prices in the data sample (i.e., daily, monthly, etc.), because of the effect of the complex pattern of serial correlation in stock returns.[18] Except for October 1987, there is little evidence that volatility measured at intervals longer than a day has increased. Indeed, realized volatility of the S&P index during 1993 was only 8.4 percent. This is exceedingly low by comparison with the

[18] See Figlewski (1994) for empirical evidence of time-variation in stock market volatility as well as a discussion of the statistical problems in measuring volatility. Brown (1990) gives an illustration of the effect of the differencing interval on measured volatility.

historical average over the last 40 years of close to 14 percent.[19]

Intraday price movements over very short intervals are larger than previously, but economists argue that higher measured volatility may actually correspond to an improvement in the quality of prices, if it means that they are adjusting more rapidly than before to new information. A reduction in the serial correlation of daily returns in recent years suggests that this may have happened.

Third, the fact that large futures price changes tend to precede similar movements in the underlying stocks is not proof that volatility originates in the futures market and is transmitted by index arbitrage into the cash market. Stock index futures are much more liquid than individual stocks and permit investors to change their exposure to the entire stock market quickly and with low transactions costs. Events with a market-wide impact can therefore be expected to be reflected initially in the futures market and then later in the stock market. Futures price movements will tend to lead those in the stock market even if the futures market is only serving as a kind of barometer for fluctuations in general investor sentiment.

Next, academics disagree that index futures trading and arbitrage are responsible for the 1987 stock market Crash. The Brady Report (1988) pointed to portfolio insurance, as being closely linked to the severity of the price decline on October 19. On the other hand, Roll (1988) analyzed the behavior of stock markets around the world during the Crash, and found little difference between the experience of those that had no index futures market or portfolio insurance trading and those that did. However, one can safely say that stock index arbitrage per

[19] See Bach and Fremault Vila (1994) for evidence on the affect of the introduction of the Nikkei 225 stock index futures contract on volatility in the stock market.

se was not a factor in the Crash. On October 19, huge backlogs of orders built up in the stock market and essentially precluded execution of arbitrage trades, and the subsequent ban on using the DOT system for arbitrage severely restricted the practice thereafter. This cut off the futures market from the cash market, and kept arbitrage from eliminating futures mispricing that was frequently extreme.

Lastly, academics mostly argue against trading halts as a way to reduce market volatility. Impeding arbitrage weakens the tie between futures prices and the underlying stock market, which reduces the value of index futures as a dependable hedging vehicle. Moreover, there is a concern that as prices approach the point at which trading will be cut off, there is a kind of "gravitational pull" toward that market level, as traders rush to complete trades before the circuit breaker is tripped. McMillan (1991) presents evidence that the circuit breakers in practice may not produce the calming effect that was hoped for.

Grossman (1988) examined the relationship between both program trading and non-program trading and stock market volatility, using daily data over the January 2, 1987 - October 30, 1987 period. The correlation between program trading intensity and volatility was statistically and economically insignificant. However, the results showed a statistically significant and positive relationship between volatility and non-program trading intensity.

Harris, Sofianos and Shapiro (1990), using 2,346 reported program trades executed at the NYSE in June 1989, analyzed the relationship among program trading, intraday stock index returns and stock index futures returns in the fifty minutes on either side of a program trade. They found many interesting results: 1) Average trading frequency begins to increase before the program trade and remains high for about 10 minutes after it; 2) The value of the cash index and the futures price begin to change before the program trade is initiated -- in fact about half of the total change occurs before the trade; 3) The absolute value of the difference between the index and the futures price is greatest before the program trade; 4) On average, there is no price reversal within the 50 minutes following the trade; and 5) Program trading is positively related to intraday volatility.

The first three of these findings imply that causality does not run exclusively from the futures to the stock market. The fourth, an important result, shows that program trading does not appear to cause overshooting and subsequent price corrections that would be associated with destabilization of the market. Points 4) and 5) together support the argument that prices changes around program trades may show increased volatility, this is due to new information entering the market. If so, the volatility is not "excess" volatility but rather fundamental volatility.

VI Conclusion

In this chapter, we have described a little of the development of the market in stock index futures. We showed the theoretical relationship between the futures price on a stock index contract and the current level of its underlying index, and explained how prices are kept in line by arbitrage. In describing how the arbitrage is actually done, we discussed program trading and generalized the cost of carry model to include the effects of transactions costs and the possibility of unwinding an arbitrage trade early. Reviewing the literature on empirical tests of the pricing model, we found that most analysts found apparent futures mispricing, both in the U.S. and in foreign markets. Mispricing tended to be larger at the outset and to diminish over time as arbitrageurs developed more efficient information and execution procedures, such as electronic transmission of computer-generated orders into the market.

Lastly, we discussed the arguments that trading in stock index futures, and especially arbitrage against the underlying stocks, led to increased volatility in the stock market. We argued that, except for the Triple Witching Hour where the link between futures and the potential for sharp price changes in the underlying stock is clear, the claim that index futures destabilize the stock market is not supported. Nor would an increase in volatility indicate that trading in index futures should be curbed--higher volatility in many cases is a result of greater informational efficiency.

One sign of the importance of futures contracts based on broad stock indexes is the fact that so many have been introduced worldwide. As Table 1 shows, despite any controversy these instruments may have generated in the U.S. over the years, countries with well developed capital markets (including the U.S., we argue) have found that the advantages of index futures trading greatly outweigh the concerns.

References

Bacha, O. and A. Fremault Vila, 1993, Multi-Market Trading and Patterns in Volume and Mispricing: The Case of the Nikkei Stock Index Futures Market, Working paper 92-33, Boston University School of Management.

Bacha, O. and A. Fremault Vila, 1994, Futures Markets, Regulation and Volatility: The Case of the Nikkei Stock Index Futures Market, *Pacific Basin Finance Journal*, forthcoming.

Brady, N., J. Cotting, R. Kirby, J. Opel, and H. Stein, 1988, *Report of the Presidential Task Force on Market Mechanisms*, Washington D.C.: U.S. Government Printing Office.

Brennan, M., and E. Schwartz, 1990, Arbitrage in Stock Index Futures, *Journal of Business*, Vol. 63, No.1 , pp. S7-S31.

Brenner, M., M. Subrahmanyam, M., and J. Uno, 1989, Arbitrage Opportunities in the Japanese Stock and Futures Markets, *Financial Analysts Journal*, 46, pp. 14-24.

Brenner, M., M. Subrahmanyam, M., and J. Uno, 1989, The Behavior of Prices in the Nikkei Spot and Futures Markets, *Journal of Financial Economics*, 23, pp. 363-383.

Brenner, M., M. Subrahmanyam, M., and J. Uno, 1989, Stock Index-Futures Arbitrage in the Japanese Markets, *Japan and the World Economy 1*, Elsevier Science Publishers B.V. North Holland, pp. 303-330.

Brown, S., 1990, Estimating Volatility, in *Financial Options: From Theory to Practice*, Figlewski, et al, eds., Homewood Ill: Business One Irwin, pp. 516-37.

Chung, Y. P., 1991, A Transactions Data Test of Stock Index Futures Market Efficiency and Index Arbitrage Profitability, *The Journal of Finance*, pp. 1791-1809.

Chung, Y. P., J-K. Kang and S. G. Rhee, 1994, Index-Futures Arbitrage in Japan, working paper.

Constantinides, G. M., 1983, Capital Market Equilibrium with Personal Tax, *Econometrica*, pp. 611-636.

Cornell, B., 1985, Taxes and the pricing of Stock Index Futures: Empirical Results, *Journal of Futures Markets*, 3, pp. 1-14.

Cornell, B., and K. French, 1983a, The Pricing of Stock Index Futures, *Journal of Futures Markets*, 3, pp. 1-14.

Cornell, B., and K. French, 1983b, Taxes and the Pricing of Stock Index Futures, *Journal of Finance*, 38, pp. 675-694.

Figlewski, S., 1984a, Hedging Performance and Basis Risk in Stock Index Futures, *Journal of Finance*, 39, pp. 657-699.

Figlewski, S., 1984b, Explaining the Early Discounts on Stock Index Futures: The Case of Disequilibrium, *Financial Analysts Journal*, July/August, pp. 43-47.

Figlewski, S., 1994, Forecasting Volatility with Historical Data, Working paper.

Finnerty, J. E., and H. Y. Park, 1988, How to Profit from Program Trading, *Journal of Portfolio Management*, pp. 41-46.

Grossman, S., 1988a, An Analysis of the Implications for Stock and Futures Price Volatility of Program Trading and Dynamic Hedging Strategies, *Journal of Business*, 61, 275-298.

Grossman, S., 1988b, Program Trading and Market Volatility: A Report on Interday Relationships, *Financial Analysts Journal*, July/August, 413-419.

Grünbichler, A., and T.W. Callahan, 1993, Stock Index Futures Arbitrage in Germany: The Behavior of the DAX Index Futures Prices, Working Paper.

Habeeb, G., J.M. Hill, and A.J. Rzad, 1991, Potential Rewards from Path-Dependent Index Arbitrage with S&P 500 Futures, *Review of Futures Markets*, Vol. 10, No. 1, pp. 180-203.

Harris, L., G. Sofianos, and J. Shapiro, 1992, Program Trading and Intraday Volatility, Working paper #90-03, NYSE.

MacKinlay, A. C., and K. Ramaswamy, 1988, Index-Futures Arbitrage and the Behavior of Stock Index Futures Prices, *Review of Financial Studies*, 1, pp. 137-158.

McMillan, H., 1991, Circuit Breakers in the S&P 500 Futures Market: Their Effect on Volatility and Price Discovery in October 1989, *Review of Futures Markets*, 10, pp.248-274.

Merrick, J., 1989, Early Unwindings and Rollovers of Stock Index Arbitrage Programs: Analysis and Implications for Predicting Expiration Day Effects, *Journal of Futures Markets*, 9, pp. 101-111.

Miller, M. H., 1993, The Economics and Politics of Index Arbitrage in the U.S. and Japan, *Pacific-Basin Finance Journal*, 1, pp. 3-11.

Modest, D.M., and M. Sundaresan, 1983, The Relationship Between Spot and Futures Prices in Stock Index Futures Markets: Some Preliminary Evidence, *Journal of Futures Markets*, 3, pp. 15-42.

Neal, Robert, 1993, Is Program Trading Destabilizing?, *Journal of Derivatives*, 1, Winter, 64-77.

Pope, P.F. and P.K. Yadav, 1994, The Impact of Short Sales Constraints on Stock Index Futures Prices: Direct Empirical Evidence From FTSE 100 Futures, *Journal of Derivatives* 1.

Roll, R., 1988, The International Crash of October 1987, *Financial Analysts Journal* 46, pp. 15-42.

Sofianos, G., 1993, Index Arbitrage Profitability, *Journal of Derivatives*, 1, Winter, pp. 6-20.

Stoll, H. R., 1988, Index Futures, Program Trading and Stock Market Procedures, *The Journal of Futures Markets*, Vol. 8, No. 4, pp. 391-412.

Stoll, H. R., and R. E. Whaley, 1986, Expiration Day Effects of Index Options and Futures, New York University, *Monograph Series in Finance and Economics*, Monograph 1986-3, New York University Salomon Center for the Study of Financial Institutions.

Stoll, H. R., and R. E. Whaley, 1987, Program Trading and Expiration-Day Effects, *Financial Analysts Journal*, March - April, pp. 16-28.

Stoll, H. R., and R. E. Whaley, 1990, Program Trading and Individual Stock Returns: Ingredients of the Triple_witching Brew, *Journal of Business*, Vol. 63, No. 1, Pt. 2, pp. S165-S192.

Tuckman, B., and J-L Vila, 1992, Arbitrage With Holding Costs: A Utility-Based Approach, *The Journal of Finance*, 4, pp. 1283-1302.

Tuckman, B., and J-L Vila, 1993, Holding Costs and Equilibrium Arbitrage, working paper.

Yadav P. K., and P. F. Pope, 1990, Stock Index Futures Pricing: International Evidence, *Journal of Futures Markets*, 10, pp. 573-603.

Table 1 Major Stock Index Futures Around the World

Country	Index	# Stocks	Weight[a]	Volume (7/27/94)	Open Interest (7/27/94)
North America					
U.S.	S&P 500	500	cap	47,481	218,769
	NYSE Composite	2089	cap	1,299	3,820
	Major Market	20	price	46	3,237
	Value Line	1665	equal	50	811
	Russel 2000	2000	cap	1,035	3,227
	Nikkei 225 (Japan)	225	equal	2,449	21,745
Canada	TSF 35	35	cap	377	NA
Europe					
U.K.	FT-SE 100	102	cap	17,373	53,474
France	CAC-40	40	cap	45,893	70,336
Germany	DAX	30	cap	16,379	98,263
Switzerland	SMI	23	cap	5,687	NA
Netherlands	EOE	25	cap[b]	1,819	NA
Spain	IBEX 35	35	cap	43,184	257,480
Sweden	OMX	30	cap	3,408	160,064
Far East, Australia					
Japan	Nikkei 225	225	equal	26,696	118,258
	Nikkei 300	300	cap	9,997	145,613
	Topix	1229	cap	8,804	73,238
Singapore	Nikkei 225 (Japan)	225	equal	32,263	92,366
Hong Kong	Hang Seng	33	cap	30,066	42,994
Australia	All Ordinaries	274	cap	4,442	71,212

Source: Bloomberg Data

[a] See footnote 4 for an explanation of index weighting methods.

Table 2: Summary of Empirical Studies on Stock Index Futures Pricing

AUTHOR	CONTRACT	PERIOD	FREQUENCY OF DATA	MARKET FRICTIONS[1]	RESULTS
Modest Sundaresan 1983	SP500	Apr. 21, 1982 - Sept. 15, 1982	Daily	TC SSP	Futures prices lie within bounds with use of at most half of short sale proceeds
Cornell French 1983	SP500 NYSE	June 1, 1982 July 1, 1982 Aug. 2, 1982 Sept. 1, 1982	Daily		Tax timing option reduces price, but not enough to eliminate the discount found during early period
Figlewski 1984	SP500	June 1, 1982 - Sept. 30, 1983	Daily		Near Contract SP500 — Full Sample / First Third / Middle Third / Last Third Mean Arbitrage Return: 0.03 / -2.88 / 2.12 / 2.54 Standard Deviation: 11.25 / 13.07 / 9.19 / 6.23 Mispricing is negative for the first period and positive thereafter. Mispricing decreases over time.
Stoll Whaley 1986	SP500	April 1982 - Dec. 1985	Hourly		The percentage of observations in which the mispricing violated the arbitrage bounds ranged from under 6% to 79% by contract. The average percentage across all contracts was 36%.
MacKinlay Ramaswamy 1988	SP500	June 17, 1983 - June 18, 1987	15 Minute Tick Data		Average mispricing was 0.12 %. Mispricing is positively related to time until maturity. Mispricing is path dependent.
Merrick 1989	SP500 NYSE	May 17, 1982 - May 30, 1986	Daily	EU	Total arbitrage profits of 178.48 index points. Unwinding profits represent 34% of total profits.
Brenner Subrahmanyam Uno 1989	NSA OSF50	June 1987 - May 1988	Daily		Mean Percentage — Absolute Deviation (Sept. 87 / June 88); Positive (Sept. 87 / June 88); Negative (Sept. 87 / June 88) NSA: 1.48 / 0.47; 0.76 / 0.17; -1.73 / -0.61 OSF50: 1.26 / 0.57; 1.74 / 0.66; -0.65 / -0.26
Yadav Pope 1990	FTSE-100	July 1, 1984 - June 30, 1988	Daily	EU	The mean percentage mispricing was -0.40 % for the overall sample. The option to unwind early or rollover an arbitrage position are valuable. The arbitrage bounds tend to be wider for longer times to expiration.
Brennan Schwartz 1990	SP500	June 17, 1983- June 18, 1987	15 Minute Tick Data	EU	Early close out option has value. Profitable to open position even if mispricing does not cover trading costs. Average profit was 0.54 index points.
Habeeb Hill Rzad 1991	SP500	Dec. 21, 1987 - June 15, 1990	5 minute Tick Data	EU EL	Excess return of 5% from both long and short. Excess return of 3% from long or short. Execution lags decrease excess returns
Sofianos 1993	SP500	Jan. 15, 1990 - July 13, 1990	Tick data Actual Arbitrage Trades	EU	Mispricings were narrow and short-lived. Most trades were unwound early. Early close out excess return of 0.1 to 4.9 % points.
Chung Kang Rhee 1994	NSA	Sept. 9, 1988 - Sept.12, 1991	1 minute Tick data	EL	The mean percentage mispricing was 0.41 % and predominantly positive for the overall sample.

1. All of the studies assumed the following market imperfections, except when noted: transactions costs (TC), full use of short sale proceeds (SSP), no uptick rule for short sales (UR), no execution lag (EL) and no early unwinding (EU). For example, if transaction costs were not included a TC appears in the column and if an execution lag was imposed, EL appears in the column.