ARBITRAGE, COINTEGRATION, AND THE JOINT DYNAMICS OF PRICES ACROSS DISCRETE COMMODITY FUTURES AUCTIONS

AARON H.W. LOW
JAYARAM MUTHUSWAMY
ROBERT I. WEBB*

Underlying the search for arbitrage opportunities across commodity futures markets that differ in market structure is the idea that the futures prices for similar commodities that are traded on different exchanges adjusted for differences in currency, delivery time (if any), location, and market structure are equal. This article examines price linkages in competing discrete commodity futures auction markets. We find no evidence of cointegration of futures prices of similar commodities traded on two contemporaneous discrete auction futures exchanges in Asia. We also find no evidence of arbitrage activities across these two Asian exchanges, though this does not preclude arbitrage activities with North American continuous auction markets. This lack of cointegration may be due to nonstationarities in the trading cost component. © 1999 John Wiley & Sons, Inc. Jrl Fut Mark 19: 799–815, 1999

*Correspondence author, 1585 Old Oaks Drive, Charlottesville, VA 22901.

- *Aaron H.W. Low is the Head of Fixed Income, Asia, and Senior Fund Manager at Dresdner Asset Management in Singapore.*
- *Jayaram Muthuswamy is an Associate Professor in the Department of Finance at the University of Sydney in Sydney, Australia.*
- *Robert I. Webb is a Professor of Finance in the McIntire School of Commerce at the University of Virginia in Charlottesville, Virginia.*

The Journal of Futures Markets, Vol. 19, No. 7, 799–815 (1999)

CCC 0270-7314/99/070799-17

INTRODUCTION

Classical economic theory suggests that financial markets are linked by the potential for incipient arbitrage. Ross (1989) and Fama (1963) contend that changes in the level and volatility of speculative prices mirror the arrival rate of new information in an informationally efficient capital market. Both factors suggest that similar commodities traded in different markets should exhibit evidence of cointegration in their long-term price dynamics.[1] Moreover, such cointegration should be observed regardless of whether the commodities are discretely or continuously traded.

This article tests that hypothesis. Specifically, it examines the joint dynamics of futures prices on storable commodities traded on two discrete auction markets: the Tokyo Grain Exchange (TGE) and the (now-defunct) Manila International Futures Exchange (MIFE) during the period October 1992 to March 1994. A surprising lack of cointegration between the two markets. is reported.

Garbade and Silber (1979) argue that the frequency of market clearing is an important structural characteristic of financial markets. Once commonplace, discrete auctions have become a relatively rare exchange mechanism in today's fast-clearing stock and commodity futures markets. Most stock and commodity futures markets allow continuous trading during the time that they are open. Some financial markets, such as the New York Stock Exchange (NYSE) and the Tokyo Stock Exchange (TSE), allow continuous trading during the trading day except at the opening (and also at the close in the case of the TSE), where a periodic call auction is employed. Other financial markets, such as the Tokyo Grain Exchange, operate periodic call auctions throughout the trading day.

Most of this literature has largely focused on markets that trade continuously when open. This study attempts to redress that deficiency by examining the joint dynamics of futures prices between two competing single fixed-price auction markets.

We believe that the joint dynamics of the price processes are important for a number of reasons. First, the two single fixed-price auction markets are highly similar except for a few subtle institutional features. Indeed, they are both variants of a discrete auction system, a process that engenders a rather unique price setting mechanism. Second, the TGE and the MIFE trade during almost contemporaneous sessions within

[1]Cointegration provides a relevant and useful econometric model for financial market data when there are either several markets or several assets. In this application, because we are studying price dynamics across different markets, it is of interest to see whether prices of similar assets in different markets have the property of being statistically close in the sense of being cointegrated—as it should be.

Asia. Third, with exception of local currency variations, a common commodity price is generated on each of these exchanges. Fourth, powerful arbitrage considerations alone should ensure that prices on the TGE and the MIFE should be very closely integrated with each other despite the time-consuming nature of the discrete auction.[2]

MARKET STRUCTURE

There is considerable evidence in the financial economic literature that suggests that market structure (that is, how a market is organized) affects the behavior of speculative prices. Many seemingly minor differences in market structure can exert a significant impact on speculative prices. One important structural characteristic of financial markets is the frequency of market clearing, as Garbade and Silber (1979) have shown.

Amihud and Mendleson (1987) examine the influence of market structure by comparing the behavior of New York Stock Exchange (NYSE) stock returns measured from an open-to-open and close-to-close basis. Amihud and Mendleson argue that opening transactions on the NYSE are generated by a "clearing mechanism," whereas closing transactions are generated by a "dealership" mechanism. This approach allows Amihud and Mendleson to control for the arrival of new information while still testing for differences in market structure. They attribute the greater observed volatility of the open-to-open stock return series over the close-to-close return series as evidence that market structure influences the behavior of speculative prices.

Unlike the NYSE, the Tokyo Stock Exchange (TSE) employs a periodic call auction (*Itayose-hoh*) at the close and open of trading. The TSE has two trading sessions during the day and allows continuous trading (*Zaraba*) between the open and close of each trading session. Amihud and Mendleson (1989) exploit this structural difference with the NYSE to examine whether the volatility of TSE open-to-open and close-to-close stock returns differ. Put simply, Amihud and Mendleson control for both market structure and the arrival of new information. They report evidence of significantly greater volatility of TSE stock returns measured on an open-to-open than close-to-close basis. They attribute the differential results to a noisy "price discovery" process, which results in an overreaction of prices at the opening.

[2]This assumes that purchasing power parity holds across countries. Changes in the real exchange rate induced by differences in expected real after-tax returns may induce seemingly persistent violations in purchasing power parity across countries.

Stoll and Whaley (1990) also report evidence of significantly greater volatility of open-to-open NYSE stock returns than close-to-close NYSE stock returns. However, Stoll and Whaley attribute the difference in volatility to private information among some market participants.

Single Fixed Price Auctions

The Walrasian tatonnement is commonly used to describe the process by which prices reach equilibrium in classical economic theory. The Itayose-hoh auction system is essentially an application of the Walrasian tatonnement to the determination of commodity futures prices.[3] That is, it is a single fixed-price auction. The auction starts when an initial provisional price is posted. Traders react to the initial provisional price by indicating the number of contracts that they are willing to buy or sell at that price. If *hana* (or excess demand) exists the futures price is raised. If excess supply exists, the futures price is lowered. This process continues until a market clearing price is established, at which point all transactions occur. Traders are free to recontract at any time prior to the determination of the final equilibrium or transaction futures price. A detailed analysis of the Itayosehoh auction system employed on the TGE (together with its implications for the price discovery process) has been studied by Marsh and Webb (1983).[4] Webb (1991) examines the behavior of provisional futures prices and the "speed" of convergence to market equilibrium. Iwata et al. (1994) use data on provisional prices and associated volumes to estimate individual trading firm demand curves. Low and Muthuswamy (1994) examine the institutional structure as well as the dynamics of the basic price formation process of the Manila International Futures Exchange (MIFE), which used a similar auction system to the TGE and traded some of the same commodities. Webb (1995) shows that noninformational factors may exert less influence on prices when the single fixed-price auction system is used.

Commodity Futures Trading on The TGE, CBT, CSCE:, and the MIFE

As noted above, soybean futures contracts are traded on a number of commodity exchanges around the world, including: the Tokyo Grain Ex-

[3]The Itayosehoh auction differs from a true Walrasian tatonnement in several important respects. First, it is a single commodity whose price is being determined, rather than the prices of all commodities simultaneously. Second, the auction process consumes time. Third, traders know exactly which firm is buying or selling and the corresponding quantities at each provisional price.

[4]Whereas the Itayose-hoh auction is widely used on Japanese commodity futures markets, some Japanese commodity futures markets, such as the Tokyo Commodity Exchange, combine periodic call auctions with Zaraba (continuous trading) for some commodities. This mechanism is also used on the Tokyo Stock Exchange.

change; the Manila International Futures Exchange; and the Chicago Board of Trade. The Chicago Board of Trade is the dominant soybean futures market in the world. Similarly, raw sugar futures contracts are traded on a number of exchanges around the world, including: the TGE; the MIFE; and the Coffee, Sugar, and Cocoa Exchange in New York.[5] The CSCE is the dominant raw sugar futures market in the world. Although the CBT, the TGE, and the MIFE all trade soybean futures contracts, significant differences exist among the commodities traded. Likewise, although the MIFE, the CSCE, and the TGE all trade raw sugar futures contracts, significant differences exist among the commodities traded. This necessitates a close analysis of the contract specifications of soybean and sugar futures contracts to determine the effects that exchange imposed differences in delivery time, location, and grade may have on prices—and hence potential arbitrage opportunities. In addition, the currency in which the contract is denominated will also affect the possible arbitrage opportunities.

TGE Soybeans are traded at: 10:00, 11:00, 13:00 and 14:00 Tokyo time. The TGE lists 6 soybean futures contracts at any one time. Delivery months are the even-numbered months extending out, at most, 12 months into the future. The contract size is 30 metric tonnes of unscreened (that is, stored in silos) yellow I.O.M. soybeans.[6] The price is quoted on a per tonne basis with the minimum price move of 10 yen per tonne. Daily price limits are decided by the Exchange on a monthly basis. The last trading day is the second business day prior to the delivery day. The delivery day is the first business day prior to the last business day of the month. The TGE soybean futures contract calls for delivery at exchange-approved warehouses in: Tokyo; Chiba; or Saitama.

In contrast, trading in imported soybean futures on the MIFE occurred at: 9:45; 10:45; 13:45; and 14:45 Manila time during the time period of this study. Because Manila is one hour behind Tokyo, this means that the shortest time between TGE and MIFE trading occurred with the first MIFE trading session—which followed the first TGE trading session by 45 minutes and preceded the second TGE session by 15 minutes. The second MIFE session occurred 45 minutes after the second TGE session and 75 minutes before the third TGE session. The third MIFE trading session occurred 45 minutes after the fourth TGE session and coincident

[5]In addition to trading imported soybeans and raw sugar, the TGE also trades azuki (or red beans) and corn as well as options on soybean and sugar futures. The Tokyo Grain Exchange merged with the Tokyo Sugar Exchange on 1 October 1993.

[6]The contract size was doubled, effective with the start of trading of the June 1994 contract. The I.O.M. designation refers to soybeans produced in one of the following three U.S. states: Indiana; Ohio; and Michigan.

with the ending of TGE soybean futures options trading. The last trading day on the MIFE was somewhat later than that on the TGE. The MIFE contract specified the last trading day as the last exchange business day before the first calendar day of the delivery month. The MIFE contract specified delivery of 500 sixty-kilogram bags of soybeans at approved warehouses in Tokyo or Kanagawa, Japan. Acceptable soybeans for delivery were either yellow soybeans produced in Dai Ren or Chin Wang Tao, China or I.O.M. soybeans from the U.S. Unlike the TGE, the MIFE traded soybean futures contracts that mature in each of six consecutive months into the future.

The Chicago Board of Trade trades soybean futures contracts under the open outcry auction method. Soybean futures trading begins at 9:30 Chicago time and ends at 13:00. At any one time, the CBT trades 9 contract months extending at most 14 months into the future. The minimum price move is 1/4 U.S. cent. The contract size is 5,000 bushels. The CBT soybean futures contract permits physical delivery of soybeans at numerous approved warehouses. Unlike the TGE, deliverable soybeans are not restricted to yellow I.O.M. soybeans.

As is readily apparent, there is a sharp difference of soybeans futures traded on the TGE, MIFE, and CBT. The effective size of the MIFE futures contract for soybeans was one fifth the size of the old TGE contract (of 15 metric tons) and one tenth the size of the new TGE futures contract of 30 metric tons. The old TGE contract is approximately one-tenth the size of a single CBT futures contract, whereas the new contract is about one fifth the size of the CBT soybean futures contract. These difference in contract size complicate potential arbitrage by raising transaction costs.

There is another factor that complicates arbitrage between the TGE and MIFE—namely, only a few delivery months overlap. Unlike the TGE, MIFE lists soybean futures contracts for six consecutive delivery months. This means that the amount of overlap is limited to the three even-numbered months contained in the sequence. This means that only three soybean futures contracts on the MIFE and TGE overlap.

There is a closer correspondence in trading session times and delivery months for raw sugar futures on the TGE and on the MIFE. Trading in raw sugar futures on the TGE are held at: 9:10; 10:20; 13:10; 14:10; and 15:10. Ten contract months are traded on the TGE, starting with the closest odd-numbered month and extending out, at most, 20 months into the future. The minimum price change is one tenth of a yen per kilogram. Maximum daily price limits vary from one and one-half yen per kilogram to three yen per kilogram, depending upon the price level. The contract size is 20,000 kilograms. The contract specifies that only imported centrifugal raw cane sugar with an average polarization of 96 degrees is acceptable for delivery. Deliverable locations include Tokyo and a number of other Japanese port cities.

There are only four trading sessions for raw sugar futures on the MIFE. They are held at: 9:15; 10:15; 13:15; and 14:15. The overlap is closest between the second TGE session and the first MIFE session. That is, the first MIFE session occurs 65 minutes after the first TGE session and 5 minutes before trading in the second TGE session begins. Similarly, trading in the first afternoon trading session on the MIFE follows trading in the second TGE afternoon session by 5 minutes, whereas trading in the last trading session on the MIFE follows trading on the TGE by 5 minutes. The minimum price move on the MIFE is one fifth of a Philippine centavo per pound. The maximum daily price limit is 10 centavos per pound from the previous closing price. Like the TGE, the MIFE sugar futures contract specifies that only centrifugal raw cane sugar with an average polarization of 96 degrees is acceptable for delivery at exchange approved locations in the Philippines. The contract calls for delivery of 50 long tons or 112,000 pounds of deliverable sugar. One key difference between the TGE and the MIFE is that the MIFE only trades 6 consecutive months out into the future. Another key difference between the MIFE and The TGE is that The TGE sugar futures contract is one third the size of the MIFE contract.

Interestingly, the size and deliverable grade specifications of the MIFE and CSCE sugar futures contracts are essentially identical. One difference in the deliverable grade specification is that the CSCE contract also lists acceptable countries of origin for deliverable sugar. (Acceptable countries of origin include the Philippines and the United States, among others.) Moreover, CSCE rules allow delivery at a port in the country of origin. The minimum price move on the raw sugar futures contract traded on the CSCE is one mill ($0.0001) per pound. The maximum daily price change is one-half cent from the previous settlement price. The CSCE trades four contract months per year (March, May, July, and October). Trading extends, at most, 18 months out into the future. Continuous trading in CSCE sugar futures contracts begins at 10:00 and ends at 13:43 New York time. The continuous trading session is followed by a closing call session that begins at 13:45.

Usually three raw sugar futures contracts traded on the MIFE and the TGE overlap at any one point in time. Similarly, at least one and sometimes three raw sugar futures contract months overlap between the

MIFE and the CSCE, depending on the time of year. This temporal overlap increases the potential for arbitrage.

One point that deserves emphasis is that the level of trading activity may differ across contract months and exchanges. As Webb (1991) has pointed out, deferred futures contracts are more actively traded than the nearby futures in Japan. The reverse is true elsewhere. This introduces another potentially important complication into the consideration of arbitrage opportunities among the various commodity futures contracts—namely, liquidity.

If the focus is on temporal proximity, then attention naturally focuses on the first, third, and fourth MIFE trading sessions for sugar futures and the second, fourth, and fifth TGE sugar futures trading sessions where trading sessions precede or follow one another by 5 minutes. In the case of soybean futures contracts, the first MIFE and second TGE soybean futures contract months are the closest in time.

Perceived arbitrage profit opportunities may disappear when freight costs are taken into account. However, freight costs can be ignored for those contracts that permit delivery in the Philippines or Japan. In the case of imported soybeans, freight costs can be ignored for the three TGE and MIFE soybean futures contracts that overlap. In the case of sugar futures contracts, freight costs can be ignored for the one to three MIFE and CSCE sugar futures contracts that overlap. The MIFE and CSCE sugar futures contracts enjoy the additional advantages that they are the same size and have the same deliverable grade. The TGE and MIFE soybean futures contracts suffer from the disadvantages of differing contract sizes and potentially different deliverable grades of commodities.

It is important to emphasize that currency risk still exists for contracts that are spatially close or temporally close. Obviously, currency risk is greatest where volatility is the greatest. Similarly, uncertainty over the deliverable grade on the MIFE contract may make arbitrage impossible. That is, given Japanese preferences for I.O.M. soybeans, the delivery of lesser grade soybeans are not acceptable. As a result, one can easily imagine a situation where TGE soybean futures prices are too high relative to Manila, yet one cannot arbitrage between the MIFE and the TGE because one cannot sell TGE soybean futures and deliver MIFE grade soybeans.

Another key institutional difference between the futures trading in Japan and the U.S. is the daily system of marking to market. In both countries daily marking to market is used. However, in Japan, traders are not able to withdraw any profits earned on a futures position although they must immediately cover any losses. In the U.S., traders have immediate access to profits and must immediately cover any losses that they

TABLE I

Summary Statistics of Log Price Changes for Sugar and Soybean Contracts for TGE and MIFE

	U.S. Dollars			Local Currency		
Contract	*Nobs*	*Mean*	*Variance*	*Nobs*	*Mean*	*Variance*
TGE Sugar	581	−0.2321	0.5057	581	0.5691	1.8875
MIFE Sugar	581	−0.2695	0.5483	581	0.3034	0.5035
TGE Soybean	707	−0.1809	0.3069	707	0.4834	1.6479
MIFE Soybean	707	−0.1547	0.2981	707	0.3160	0.5830

Notes: Nobs denotes number of observations and magnitudes of means and variances are in 10^{-2}

incur on their futures positions. The net effect of this institutional difference is that Japanese futures prices are closer to true forward prices than U.S. futures prices, where the interim gains can be invested or the losses borrowed.

DATA AND SUMMARY STATISTICS

We use daily data on soybean and sugar futures contracts from both MIFE and TGE over the period October 1992 to March 1994. This basically covers the full trading price series for six futures contracts. Prices from the TGE are quoted in Japanese yen, whereas prices from MIFE are in Philippine pesos. The futures data was provided by TGE and Panwell Investments. Our prices are also translated into U.S. dollar values using day-end exchange rates obtained from the *Business Times*. Excluding weekends and holidays, the average number of daily observations range from 91 to 110 for sugar contracts and 98 to 120 for soybean contracts.

The summary statistics in Table I show the mean and variance of log price changes for all four different commodity contracts in both U.S. dollars and local currencies. There are some interesting observations peculiar to the duration and currency denomination. Overall positions for both commodities show negative returns due to the U.S. dollar appreciation during the 1993–1994 period. The appreciation was greater against the Japanese yen than Philippine peso. Volatility of price changes also tend to be greater in local currencies than in U.S. dollar terms. In particular, it is interesting to note that both sugar and soybean contracts have higher returns and higher return volatility on the TGE compared to MIFE when measured in local currency terms. Given the much larger volume of transactions on the TGE, one possible explanation could be that the TGE better reflects public information in futures prices compared to the MIFE. The presence of arbitrage activities between TGE and the North American exchanges compared to the lack of such activities on the MIFE (seen in the next section) provides further support for greater efficiency on the TGE.

ARBITRAGE

Classical economic theory and common sense alike suggest that financial markets are linked by the potential for arbitrage. Whereas this is easily seen with respect to continuous markets, it is not as immediately apparent for discrete auction markets.

The concept of arbitrage is central to modern financial economic theory. For instance, the realization that, in the absence of arbitrage profit opportunities, the return on a perfectly hedged security position has an expected return equal to the risk-free interest rate was the crucial insight that led Black and Scholes (1973) to develop the first general equilibrium option pricing model.

True arbitrage represents a risk-free zero-investment profit opportunity. It entails the simultaneous purchase and sale of a commodity or security in the same or different markets such that a risk-free profit results. Arbitrage has long been used as a driving force in markets. Incipient arbitrage (or the mere potential for arbitrage) drives many arguments about the behavior of speculative prices.

It should be immediately apparent that discrete auctions that occur at different times are not subject to true arbitrage. Rather, the test is whether quasi-arbitrage profit opportunities exist. Virtually risk-free profit opportunities may still arise in such markets, especially if changes in speculative prices respond primarily to the arrival of new information rather than noise. Whether a positive investment is required in such markets may depend upon the institutional details. In any event, the possibility of arbitrage imposes some severe constraints on the behavior of speculative prices in two discrete auction markets.

Many arbitrage opportunities are more apparent than real. Miller, Muthuswamy, and Whaley (1994) demonstrate that the existence of mean reversion in the basis between cash and futures stock index "prices" may arise from infrequent trading of the component stocks in the cash market rather than the actions of arbitrageurs. In this instance, infrequent trading arises not as a result of the market mechanism (for example, as it would in a periodic call auction) but rather as a result of the transactions preferences of market participants. Moreover, they contend that the commonly observed negative autocorrelation of changes in the basis would arise even in the absence of arbitrage.

Consider two different futures prices, $F^T_{t\backslash t+k}$ and $F^M_{t\backslash t+k}$, at time t for k periods forward, on the same commodity traded on exchanges T and M. One form of relationship is the following:

$$F^T_{t\backslash t+k} = F^M_{t\backslash t+k} + S_{t\backslash t+k}{}^*C_t$$

where $S_{t\backslash t+k}$ is the forward exchange rate at time t for k periods hence, and C_t is a term incorporating transportation differentials, transactions and trade barrier costs. Taking logs on both sides and assuming that C_t remains constant over short durations, we can derive the following:

$$\Delta \ln F^T_{t\backslash t+k} = \Delta \ln F^M_{t\backslash t+k} + \Delta \ln S_{t\backslash t+k}$$

Assuming that C_t is stationary, the above relationship would hold in the presence of arbitrage activities. We can represent this quasi-arbitrage equation by the following:

$$\Delta \ln F^T_{t\backslash t+k} = \alpha + \beta_1 \cdot \Delta \ln F^M_{t\backslash t+k} + \beta_2 \Delta \ln S_{t\backslash t+k} + \varepsilon_t$$

Our null hypothesis of the existence of arbitrage activities is indicated by the regression coefficients ($\alpha = 0$ and $\beta_1 = \beta_2 = 1$. For sugar contracts, the results of our regression yields:

$$\begin{aligned}\Delta \ln F^T_{t\backslash t+k} = {} & -0.00011 + 0.4208 \cdot \Delta \ln F^M_{t\backslash t+k} + 0.5132 \cdot \Delta \ln S_{t\backslash t+k} \\ & (0.00043) \quad (0.2142) \qquad\qquad\qquad (0.3857)\end{aligned}$$

with standard errors in parentheses. For soybean contracts, the results are:

$$\begin{aligned}\Delta \ln F^T_{t\backslash t+k} = {} & -0.00013 + 0.2522 \cdot \Delta \ln F^M_{t\backslash t+k} + 0.4786 \cdot \Delta \ln S_{t\backslash t+k} \\ & (0.00027) \quad (0.1861) \qquad\qquad\qquad (0.0723)\end{aligned}$$

Although α is insignificant, β_1, β_2 do not show strong evidence of cross-trading. The rejection of the presence of arbitrage activities between MIFE and TGE shown in the quasi-arbitrage regressions above for both commodities is further substantiated by the authors' conversations with commodity traders on the TGE. However, these traders did acknowledge the existence of arbitrage trading between the TGE and the CBT as well as the CSCE.

LONG TERM PRICE DYNAMICS

Tests for Unit Roots

First we test for the presence of unit roots in futures prices using the Augmented Dickey-Fuller regressions. If commodity prices contain unit roots then the problem of spurious regressions may arise. Unless a nonstationary process is combined with another nonstationary process to yield a stationary cointegration relationship, then regressions involving the price levels can give false results.

The test statistics are based on the OLS estimation results from the augmented Dickey-Fuller equations,

$$\Delta F_t = \alpha_0 + \alpha_1 \cdot F_{t-1} + \sum_{j=1}^{p} \gamma_j \cdot \Delta F_{t-j} + \eta_t$$

where ΔF_t is the change in futures prices at time t and p is the number of lagged terms that is chosen to whiten the error terms. When $\alpha_1 = 0$, the futures price F_t is nonstationary. We also report the Phillips-Perron nonparametric method, which also corrects for serial correlation.

Tables II and III show the results of unit root tests for sugar and soybean futures denominated in their respective currencies as well as the common U.S. dollar. The results generally support the null hypothesis and indicate presence of unit roots in price levels. In all cases, the test statistics are not significant at the 5% level, and most are not significant at the 10% level. Our results (not shown here) of Dickey-Fuller tests on first differences also support stationarity and confirms that both futures prices are I(1).

Cointegration

To evaluate whether there exists a linear combination of cross market futures prices on the same commodity that is stationary, we use the standard cointegrating regressions;

$$F^M_{t\backslash t+k} = \alpha + \beta \cdot F^T_{t\backslash t+k} + \varepsilon_t$$

TABLE II

Unit Root Tests for Sugar and Soybean Contracts in U.S. Dollars

	TGE (US$)			*MIFE (US$)*		
Contract	*Lags*	*ADF stat*	*PP stat*	*Lags*	*ADF stat*	*PP stat*
Sugar						
May 93	0	0.958	0.839	4	0.646	1.726
Jul 93	0	−1.621	−1.621	7	−1.197	−1.132
Sep 3	6	−0.486	−0.711	1	−1.732	−1.499
Nov 93	8	−2.534	−1.581	0	−1.802	−1.799
Jan 94	7	−1.849	−2.136	2	−0.375	−0.710
Mar 94	9	−1.754	−1.776	0	−1.767	−1.687
Soybean						
Apr 93	0	−0.366	−0.416	0	−2.371	−2.414
Jun 93	0	−1.413	−1.391	7	−0.505	−1.189
Aug 93	7	−0.529	−0.760	0	−1.314	−1.336
Oct 93	0	−1.360	−1.356	0	−1.239	−1.359
Dec 93	0	−1.505	−1.503	0	0.146	0.279
Feb 94	7	−3.397[a]	−3.512[a]	2	−2.833[a]	−1.954

Notes: Augmented Dickey-Fuller (ADF) t-statistics are shown in the optimal lag structures. The Phillips-Perron (PP) test statistics are also indicated. Significance at the 10% confidence level is indicated by[a], and at the 5% level by[b].

TABLE III

Unit Root Tests for Sugar and Soybean Contracts in Units of Local Currency

	TGE(Yen)			*MIFE(Peso)*		
Contract	*Lags*	*ADF stat*	*PP stat*	*Lags*	*ADF stat*	*PP stat*
Sugar						
May 93	0	0.549	0.574	4	0.937	2.035
Jul 93	0	−1.575	−1.132	1	−1.109	−1.632
Sep 93	0	−0.072	−0.249	1	−1.952	−1.774
Nov 93	8	−2.794[a]	−1.566	0	−1.1651	−1.640
Jan 94	0	−1.901	−1.930	0	−0.539	−0.548
Mar 94	4	−2.268	−1.777	1	−1.588	−1.949
Soybean						
Apr 93	0	−2.699[a]	−2.698[a]	0	−2.583[a]	−2.673[a]
Jun 93	0	−1.051	−1.041	1	−0.897	−0.581
Aug 93	7	−1.200	−1.574	0	−0.812	−0.807
Oct 93	0	−1.346	−1.444	0	−1.705	−1.743
Dec 93	7	−1.699	−1.655	2	−0.407	0.146
Feb 94	7	−2.893[a]	−3.502[a]	2	−3.105[a]	−2.072

Notes: Augmented Dickey-Fuller (ADF) t-statistics are shown with the optimal lag structures. The Phillips-Perron (PP) test statistics are also indicated. Significance at the 10% confidence level is indicated by [a], and at the 5% level by [b].

TABLE IV

Cointegration Test Statistics for the Relationship $F^M_{t\backslash t+k} = \alpha + \beta \cdot F^T_{t\backslash t+k} + \varepsilon_t$

	ADF stat				
Contract	*Lag*	*t-stat*	*Phillips stat*	R^2	*DW stat*
Sugar					
May 93	0	−0.858	−0.848	0.783	0.087
Jul 93	6	−0.880	−1.578	0.929	0.200
Sep 93	0	−1.574	−1.708	0.674	0.104
Nov 93	8	−1.146	−2.284	0.811	0.229
Jan 94	7	−0.242	−0.937	0.189	0.069
Mar 94	0	−1.911	−1.839	0.065	0.136
Soybean					
Apr 93	0	−2.448	−2.494	0.041	0.207
Jun 93	0	−2.108	−2.304	0.560	1.202
Aug 93	5	−1.946	−2.188	0.532	0.139
Oct 93	0	−2.018	−2.062	0.409	1.182
Dec 93	5	−0.003	−0.468	0.524	0.095
Feb 94	2	−2.493	−1.701	0.049	0.081

Notes: ADF denotes the augmented Dickey-Fuller statistics and DW is the Durbin-Watson statistic for serial correlation. The lag structure for the ADF statistic is chosen to minimize serial correlation in error terms.

where we choose MIFE, $F^M_{t\backslash t+k}$, prices as the regressand. The turnover on TGE is around 10 times larger than that of MIFE and it makes sense to examine statistical influences from TGE to MIFE rather than the reverse. The residual based test for no cointegration is given by a similar test for a unit root in the estimated residuals It and the augmented Dickey-Fuller equation is

$$\Delta\hat{\varepsilon}_t = \theta \cdot \hat{\varepsilon}t_{t-1} + \sum_{j=1}^{p} \chi_j \cdot \hat{\varepsilon}_{t-j} + \upsilon_t$$

where we use the t-ratio test for $\theta = 0$. We also report the Phillips unit root statistics, which is a nonparametric correction for serial dependency.

Table IV shows results that do not support cointegration between TGE and MIFE prices. Our ADF and Phillips t-statistic are not significant at the 10% level. The R^2 and Durbin-Watson statistics are also consistent with this finding. These results may not be too surprising given the absence of cointegration in cash and futures prices in other commodity markets. Baillie and Myers (1991), Bessler and Covey (1991), Chowdhury (1991), and Schroeder, and Goodwin (1991) all find no evidence of cointegration between spot and futures prices in various storeable and nonstoreable commodity markets.

Such implications are important for various reasons. The lack of a cointegrating relationship implies we may have to review forecasting models, cross-hedging models, and tests of other economic relationships. More importantly, it is critical to understand the lack of a cointegrating relationship in the standard model for commodities. One possibility could be due to the nonstationarity of the costs-of-carry term. We can restate our original relationship:

$$F^{T}_{t\backslash t+k} = F^{M}_{t\backslash t+k} * S_{t\backslash t+k} * C_t * \exp[Q^{*}_{t\backslash t+k}]$$

where $Q_{t\backslash t+k}$ is an adjustment term for differences in marking to market features of futures contracts traded on MIFE and TGE. This relationship can be restated in U.S. dollar terms;

$$F^{T,us}_{t\backslash t+k} = F^{M,us}_{t\backslash t+k} * C^{us}_t * \exp[Q^{*}_{t\backslash t+k}]$$

Taking logs, the price dynamics can be decomposed into the following:

$$\ln F^{T,us}_{t\backslash t+k} = \ln F^{M,us}_{t\backslash t+k} + \ln C^{us}_t + Q^{*}_{t\backslash t+k}$$

Following the argument of Brenner and Kroner (1995), it is now obvious that if the logs of the MIFE futures price and the differential costs C^{us}_t are not cointegrated with cointegration vector $(1, -1)$, then $\ln F^{T,us}_{t\backslash t+k}$ has a stochastic trend. The main implication of this proposition is that if the cost differential has a stochastic trend, then futures prices on different exchanges will not be cointegrated by themselves if the cost differential is excluded. Cointegration can be realized only if this differential term is included in the cointegrating regression.

CONCLUSIONS

Underlying the search for arbitrage opportunities across commodity futures markets that differ in market structure is the idea that the futures prices for virtually identical commodities that are traded on different exchanges adjusted for differences in currency, delivery time (if any), location and market structure are equal. It is natural to contend that incipient quasi-arbitrage constrains the price behavior of futures contracts traded on discrete auctions. Instead, we find surprising results that show a lack of arbitrage activities across the MIFE and TGE contracts. Also, futures prices on both exchanges do not show evidence of cointegration.

Like other results on cash-futures cointegration, this could result from nonstationarity in costs-of-carry and trading costs differentials for storable commodities.

BIBLIOGRAPHY

Amihud, Y., & Mendleson, H. (1987). Trading mechanisms and stock returns: An empirical investigation. Journal of Finance, 42(3), 533–553.

Amihud, Y., & Mendleson, H. (1989). Market microstructure and price discovery on the Tokyo Stock Exchange. Japan and the World Economy, 1, 341–370.

Black, F. (1986). Noise. Journal of Finance, 41, 529–543.

Engle, R. F., Ito, T., & Lin, W. (1990). Meteor showers or heat waves? Heteroskedastic intra-daily volatility in the foreign exchange market. Econometrica, 58(2), 525–542.

Brenner, R. J., & Kroner, K. (1995). Arbitrage, cointegration, and testing the unbiasedness hypothesis in financial markets. Journal of Financial and Quantitative Analysis, 30(1), 23–42.

Engle, R. F., & Ng, V. (1992). Measuring and testing the impact of news on volatility. Journal of Finance, 48(5), 1749–1778.

Fama, E. F. (1963). Mandlebrot and the stable paretian hypothesis. Journal of Business, 36(4), 420–429.

Futures Industry Institute (1993). Futures Industry Institute factbook. Washington, DC: Futures Industry Institute.

Garman, M. (1976). Market microstructure. Journal of Financial Economics, June, 257–275.

Garbade, K. D., & Silber, W. L. (1979). Structural organization of secondary markets: Clearing frequency, dealer activiety and liquidity risk. Journal of Finance, 34(3), 577–593.

Hamao, Y., Masulis, R., & Lin, V. (1990). Correlations in price changes in volatility across international stock markets. Review of Financial Studies, 3, 281–308.

Iwata, G., Fujiwara, K., Sunada, H., Iida, N., & Yoshida, J. (1994). A study of tatonnement process. In Itayose-Hoh auction trading. Keio Economic Observatory occasional paper, Sangyo Kenyujo, Keio University, April.

Kim, S. W., & Roger, J. (1995). International stock price spillovers and market liberalization: Evidence from Korea, Japan, and the United States. Journal of Empirical Finance, 2, 117–133.

Lin, W., (1994). Interdependence between international stock returns news or contaigon effect? Social Systems Research Institute working paper, University of Wisconsin–Madison, September.

Low, A., & Muthuswamy, J. (1994). Investigation of a discrete futures auction exchange: The case of the Manila International Futures Exchange. Review of Futures Markets, 13(4), 1123–1149.

Marsh, T. A., & Webb, R. I. (1983). Information dissemination uncertainty: The continuity of trading and the structure of international futures markets. Review of Research in Futures Markets, 2(1), 36–71.

Miller, M., Whaley, R. & Muthuswamy, J. (1994). Mean reversion of S&P 500 index basis changes: Arbitrage-induced or statistical illusion? Journal of Finance, June .

Ross, S. A., (1989). Information and volatility: The no-arbitrage martingale approach to timing and resolution irrelevance. Journal of Finance, 43, 116.

Stoll, H., & Whaley, R. (1990). Stock market structure and volatility. Review of Financial Studies, 3, 37–71.

Webb, R. I. (1991). The behavior of "false" futures prices. The Journal of Futures Markets, 11(6), 651–668.

Webb, R. I. (1995). Futures trading in less "noisy" markets. Japan and the World Economy, 7, 155–173.