International transmission of information in corn futures markets

G. Geoffrey Booth *, Cetin Ciner

Department of Finance, Louisiana State University, Baton Rouge, LA 70803, USA

Abstract

This paper examines the information transmission mechanism between corn futures traded in Tokyo and Chicago for the 1993–1995 period. Corn futures contracts traded on the Chicago Board of Trade (CBT) and the Tokyo Grain Exchange (TGE) have almost identical specifications. Different trading systems are used by the two exchanges, and their trading times do not overlap. Dynamic vector autoregression models are employed to test for price and volatility spillovers between the markets. The results indicate that the TGE is dependent on the CBT for information generation, which is reflected in the opening price of the TGE.

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Keywords: Information transmission; International futures markets; Variance autoregression

1. Introduction

In the last decade, financial market research has increasingly focused on the interaction between markets. One particular thrust of this effort is to examine price and volatility spillover between international markets. Because of their size, it is not surprising that the relationship between US and Japanese markets has been of particular interest. Stock market interactions, with the market being proxied by a comprehensive stock index, have received the bulk of the attention. Recent examples of this research genre include Hamao et al. (1990), Bae and Karolyi (1994), Koutmos and Booth (1995) and Lin et al. (1995). Other markets which also have been investigated include stock index futures (Booth et al., 1996a and Booth et al., 1996c), Eurodollar futures (Tse et al., 1996) and foreign exchange (Engle et al., 1990).¹

¹ Booth et al. (1996c) and Tse et al. (1996) use the Nikkei and Eurodollar futures contracts traded on the Singapore International Monetary Exchange (SIMEX) to proxy the Japanese markets. SIMEX is designed to attract Japanese participants and has adjusted its trading hours to coincide with Japanese on-shore markets.
Although the specific results of these studies differ, the general conclusion is that Japanese and US financial markets interact in some way.

The purpose of this paper is to further the understanding of the interaction between Japanese and US markets (and markets in general) by examining the information transmission behavior of the corn futures contracts traded on the Chicago Board of Trade (CBT) and the Tokyo Grain Exchange (TGE). Corn is traditionally an American agricultural product, and a US No. 2 yellow corn futures contract has been active on the CBT since 1877. The TGE launched its own successful futures contract on imported US No. 2 yellow corn in April 1992. Since these two futures are derivatives of the same cash crop, it is natural to believe that their prices react in a similar manner to news concerning the cash crop. However, since this news is released during US business hours when the TGE is closed, whether the CBT futures or the TGE futures is first to react to the news depends on whether the news was released during or after CBT trading hours. If the announcement occurs during CBT trading hours and the CBT reacts quickly, price and volatility spillover should emanate from this market. If the innovation occurs after the close of the CBT, the TGE should react first.

To accomplish this purpose, vector autoregression (VAR) models are used to examine intermarket spillovers present in unexpected returns and volatilities. The statistical tests derived from these models indicate that intraday CBT returns significantly affect overnight returns of the TGE corn futures. However, no significant information spillover is found from CBT trading returns to TGE trading returns or vice versa. These findings indicate that information produced during CBT's trading time is relevant to the TGE and that this information is completely incorporated overnight and is expressed in the opening price. The effect of overnight information spillover from the CBT is not observed in the intraday price behavior of the TGE because the single fixed-price trading system used by the TGE allows transactions to occur only at equilibrium prices.

The organization of the rest of the paper is as follows. Section 2 discusses the data environment, explains the trading mechanisms of the two markets and provides descriptive sample statistics of the series. Section 3 describes the price spillover VAR and presents the empirical results. Section 4 tests for volatility spillovers, and Section 5 offers concluding remarks.

2. Data and international corn futures markets

Data used in this study are the daily open and close prices of the CBT and TGE corn futures between 4 January 1993 and 30 June 1995. Table 1 summarizes the

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2 Marsh and Webb (1983) and Webb (1991) examine almost identical soybean futures traded on the CBT and the TGE. They analyze the effects of the different trading mechanisms used by the two exchanges on price variability, compare the volatility patterns of similar maturity contracts from the two exchanges, and report that the single fixed-price auction system used by the TGE is efficient in incorporating new information into future prices.

3 This timing of announcements is not uncommon. For example, the US Department of Agriculture releases its weekly crop report on Tuesdays after the close of CBT trading.
<table>
<thead>
<tr>
<th></th>
<th>CBT</th>
<th>TGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launched</td>
<td>2 January 1877</td>
<td>20 April 1992</td>
</tr>
<tr>
<td>Contract size</td>
<td>5000 bushels (126 000 kilograms)</td>
<td>(3968 bushels) 100 000 kilograms</td>
</tr>
<tr>
<td>Contract grade</td>
<td>US No. 2 yellow corn</td>
<td>US No. 2 yellow corn with less than 15% moisture</td>
</tr>
<tr>
<td>Contract months</td>
<td>March, May, July, September and December</td>
<td>January, March, July, September and November</td>
</tr>
<tr>
<td>Trading hours</td>
<td>8:30 to 13:15 Chicago time</td>
<td>18:10 to 0:10 Tokyo time</td>
</tr>
<tr>
<td></td>
<td>21:30 to 4:15 Tokyo time</td>
<td>9:10 to 15:10 Tokyo time</td>
</tr>
<tr>
<td>Minimum price fluctuation</td>
<td>0.250 cents per bushel (9.92 yen per 1000 kg)</td>
<td>(0.252 cents per bushel) 10 yen per 1000 kg</td>
</tr>
<tr>
<td>Method of settlement</td>
<td>Physical delivery, Chicago</td>
<td>Physical delivery, CIF Tokyo</td>
</tr>
</tbody>
</table>

One bushel of corn weighs 25.2 kilograms. The exchange rate between the US and Japan is assumed as 100, as an approximation to its average value over the span of this study, to calculate the minimum fluctuation of CBT contract per kilogram. Values in parentheses are conversions.

Trading hours as well as the specifications of the contracts. Trading on the CBT is conducted between 8:30 (21:30) and 13:15 (4:15) Chicago (Tokyo) time. The CBT currently offers five contract months on corn futures (March, May, July, September and December). Contracts expire on the last business day of the month. The underlying commodity is US No. 2 yellow corn and the method of settlement is physical delivery. The underlying commodity of the TGE contract is also US No. 2 yellow corn. Trading hours on the TGE are between 9:10 (18:10) and 15:10 (0:10) Tokyo (Chicago) time, with four trading sessions contained therein. Thus, the trading times of the TGE and CBT do not overlap. The TGE trades six contract months (January, March, May, July, September and November). The method of settlement on the TGE is physical delivery, Customs Insurance and Freight (CIF) Japan, and the last trading day is the 15th day of the month preceding the delivery month.

The trading patterns observed on these two markets differ markedly. To illustrate, Table 2 provides trading volume figures from the markets for the first three months of 1995. It is generally accepted as a stylized fact that nearby contracts are the most active and that more information is contained in these contracts. CBT corn futures volume conforms to this pattern, nearby contracts being more active, with the December contract being the exception. The December contract is usually more active than the September contract because by December most of the information concerning the US corn supply is available. Therefore, December contracts are widely used by grain-trading houses, grain-marketing firms and farmers. This seasonality is well documented in the agricultural economics literature (see Leath and Garcia, 1983, among others). However, the most deferred (farthest) contracts are the most active on the TGE. For example, in January 1995, 462 657 corn futures contracts (583 942 TGE equivalent) with a delivery date of March 1995 were traded on the CBT, while in the same month only 6206 contracts with a delivery date of
Table 2
CBT and TGE corn futures contracts trading volumes in the first three months of 1995

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CBT</td>
<td>TGE</td>
</tr>
<tr>
<td>CBT</td>
<td>462,657</td>
<td>115,157</td>
<td>100,413</td>
</tr>
<tr>
<td>TGE</td>
<td>620,657</td>
<td>10,717</td>
<td>20,667</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CBT</td>
<td></td>
<td>73,400</td>
<td></td>
<td>7106</td>
</tr>
<tr>
<td>TGE</td>
<td></td>
<td></td>
<td></td>
<td>89,53</td>
</tr>
</tbody>
</table>

Figures in italics represent the 'corn weight equivalent' of CBT trading volume to TGE trading volume. The total weight of corn, in kilograms, traded on two exchanges can be calculated by multiplying the TGE volume and the numbers in italics by 100,000.

March 1995 were traded on the TGE. In contrast, 110,388 contracts with a delivery date of March 1996 were traded on the TGE.4

Identical futures contracts which are traded on different exchanges are often hypothesized to constitute segments of a combined market which shares the same information mechanism. For instance, Tse et al. (1996) show that the markets in which Eurodollar futures are traded constitute the segments of a continuously trading market. Booth et al. (1996c) report that the same phenomenon holds for Nikkei futures, which are also traded worldwide. Finally, Booth et al. (1996a) find that Canadian wheat futures traded on the Winnipeg Commodity Exchange (WCE) and CBT wheat futures are related in the long run.5 In the same spirit, futures traded on the CBT and the TGE are hypothesized to constitute the segments of a

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4 It is unclear why the farthest Japanese contract is the most heavily traded, and communication with TGE officials did not resolve the issue. It may be a result of the TGE's market architecture, a point which will be made later. It may also be that those buying the Japanese contract are speculating on next year's crop. Nevertheless, to the extent that the news is relevant to the current and next year's crops, there may be some dependency between the two markets. For instance, the news may be the announcement of the development of a persistent weather pattern. Mandelbrot and Wallis (1968) dub this persistence the 'Joseph effect', after the biblical reference to seven years of feast and seven years of famine. The sensitivity of crop futures prices to weather changes, at least in the short run, is dramatically illustrated by Roll (1984).

5 Although the underlying cash crop is wheat, WCE wheat is used only for animal feed, while CBT wheat is generally for human consumption. Booth et al. (1996b), however, point out that the relationship between the two contracts is largely influenced by the market actions of the Canadian Wheat Board.
combined corn futures market, and are expected to have informational dependencies (spillovers).

Prices of the farthest TGE contracts in a 12-month period are used, and these data were supplied by the TGE. CBT prices were provided for the most active (generally the nearest) contracts by the CBT. In constructing CBT price series, the September contract is replaced by the December contract since the volume of this latter contract is greater. Contracts are switched at the beginning of expiration months. Following Heinkel and Kraus (1988) and many others, prices are assumed to stay the same as the previous trading day when data are not available due to different trading days, thereby producing 647 observations.

Before proceeding to the empirical analysis, some information on the trading systems of the two exchanges is in order. As explained by Webb (1991), the CBT trading system can be characterized as a continuous open-outcry auction which generates a virtually continuous stream of futures prices. At any moment and for every contract, there is always at least one bid price and one ask price on the floor. A transaction price results whenever someone hits a bid or takes an offer. There is no assurance, however, that the transaction price represents the market clearing price. There are two reasons for this. First, the stated quantity demanded (supplied) at a bid (offer) price may not reflect the total quantity demanded (supplied). Second, whenever apparent excess demand (supply) exists, the initial quantity offered (bid) may be taken before the offer (bid) price can rise (fall) to reflect the additional demand (supply).

The TGE, however, uses the ‘Itayose-hoh’ or single fixed-price auction. This system generates a single equilibrium price for each of the four trading sessions, and is similar to a single-commodity Walrasian auction. In the Itayose-hoh, if in total the quantity supplied differs from the quantity demanded, no transaction occurs. In response, the price is altered by market officials and the quantities supplied and demanded are solicited from the traders at new provisional prices. When there is no excess demand or supply, the provisional price becomes the final or ‘equilibrium’ price. An important aspect of the TGE’s trading system is that auctions on various contracts are conducted by the order of the expiration of the contract, with the nearest contract being first. Presumably, a change in the equilibrium price from the previous trading session reflects new information, and this change may also be relevant to the next futures contract. Accordingly, the market opening price is adjusted to reflect the price change, if any, from the auction of the preceding contract month. This process suggests a possible reason why the more distant TGE contracts are more active than the nearby contracts. More information is always available for the more distant contracts as a result of this particular trading system.

Financial researchers have recently paid considerable attention to the effects of the trading systems on efficient price discovery. In this respect, there is mounting evidence in the literature that the Itayose-hoh method is an efficient trading system. For example, Amihud and Mendelson (1991) examine the Itayose-hoh system used in the opening of the Tokyo Stock Exchange. Their sample include US-traded Japanese stocks, which represents a very similar case to corn futures in terms of trading hours. They conclude that Itayose-hoh might well be the most efficient
method of value discovery, and the opening price reflects accumulated information from overnight (in Tokyo) US trading. Webb (1991) examines the speed of convergence to equilibrium of the provisional prices of the US soybeans contract traded on the TGE. He also concludes that equilibrium is reached very quickly in the single fixed-price auction employed by the TGE.

Since there is no trading-time overlap between the two markets, trading (intraday) returns, defined as the difference between the natural logarithms of close and open prices, and nontrading (overnight) returns, defined as the difference between the natural logarithms of open and previous close prices, are used to investigate the nature of the information transmission mechanism. Table 3 provides sample statistics describing these returns. TGE and CBT trading returns, on average, are zero, negatively skewed and relatively thick-tailed. Ljung–Box statistics, although upwardly biased in the presence of heteroskedasticity, indicate that these TGE and CBT returns are independent in the first moments. Lagrange multiplier statistics, however, indicate the presence of significant GARCH effects, a phenomenon consistent with the observed significant excess kurtosis. The nature of TGE and CBT nontrading returns is similar to their trading returns, with the exception of skewness. TGE nontrading returns are symmetric and the corresponding CBT returns are positively skewed.

The stationarity of the four return series are tested as suggested by Dickey and Fuller (1979). To complement this test (ADF), the unit root test (PP) developed by Phillips (1987) and Perron (1988) is used. The latter test is predicated on the

<p>| Table 3                                                                 |
|---|---|---|---|---|---|
| Trading returns                                                                 |</p>
<table>
<thead>
<tr>
<th>TGE</th>
<th>CBT</th>
<th>TGE</th>
<th>CBT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of observations</td>
<td>647</td>
<td>647</td>
<td>647</td>
</tr>
<tr>
<td>Mean (10^-4)</td>
<td>0.71 (0.81)</td>
<td>0.66 (0.83)</td>
<td>0.22 (0.53)</td>
</tr>
<tr>
<td>Variance (10^-4)</td>
<td>0.58</td>
<td>0.67</td>
<td>0.85</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.02 (0.82)</td>
<td>-0.32 (&lt; 0.01)</td>
<td>-0.13 (0.17)</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>1.29 (&lt; 0.01)</td>
<td>1.90 (&lt; 0.01)</td>
<td>1.00 (&lt; 0.01)</td>
</tr>
<tr>
<td>LB(3)</td>
<td>4.28 (0.23)</td>
<td>6.25 (0.10)</td>
<td>1.76 (0.62)</td>
</tr>
<tr>
<td>LB(5)</td>
<td>4.91 (0.42)</td>
<td>6.50 (0.26)</td>
<td>6.55 (0.08)</td>
</tr>
<tr>
<td>LM(12)</td>
<td>75.05 (&lt; 0.01)</td>
<td>48.23 (&lt; 0.01)</td>
<td>50.07 (&lt; 0.01)</td>
</tr>
<tr>
<td>ADF</td>
<td>-12.64</td>
<td>-12.20</td>
<td>-13.78</td>
</tr>
<tr>
<td>PP</td>
<td>-25.53</td>
<td>-27.24</td>
<td>-10.32</td>
</tr>
</tbody>
</table>

p-values are in parentheses. LB(n) is the Ljung–Box statistic at lag n, χ² distributed. LM(n) is the Lagrange multiplier test for heteroskedasticity as in Engle (1982). The augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) test statistics for unit root are computed with a constant and a linear trend. Three lags and three non-zero autocovariances in the Newey-West (Newey and West, 1987, 1994) correction are used for the ADF and the PP tests, respectively. The results are robust for five and ten lags. The critical values for both tests are asymptotically equivalent and are provided by Fuller (1976) (p. 373).
assumption that the time series to be examined is autocorrelated, but it is reported
to be robust with respect to heteroskedasticity. The results for the unit root tests
are also provided in Table 3. In all cases, the unit-root hypothesis is soundly rejected,
regardless of which test is employed.\(^6\) Hence, returns may be considered as mean
stationary and can be used in the VAR model directly.

3. Testing for price spillovers

A multivariate VAR model is used to investigate the presence of price spillovers
between the markets. VAR models, popularized by Sims (1980), provide a flexible
framework to examine the dynamic interactions and possible lead-lags between the
markets. These models are especially well suited for the problem at hand, since they
infer relationships from the data without employing any a-priori theoretical restric-
tions. Each variable is treated as endogenous and is regressed on lagged values of
all variables in the system.

Assuming equal information lags in both markets, and recognizing the differences
in real time, the following VAR system is established

\[
CT_t = a^{CT} + \sum_{i=1}^{n} b_i^{CT} CT_{t-i} + \sum_{i=0}^{n-1} c_i^{CT} CT_{i-t-i} \\
+ \sum_{i=0}^{n-1} d_i^{CT} TT_{t-i} + \sum_{i=0}^{n-1} e_i^{CT} TN_{t-i} + CT_t, \quad (1a)
\]

\[
CN_t = a^{CN} + \sum_{i=1}^{n} b_i^{CN} CT_{t-i} + \sum_{i=0}^{n} c_i^{CN} CT_{t-i} \\
+ \sum_{i=0}^{n-1} d_i^{CN} TT_{t-i} + \sum_{i=0}^{n} e_i^{CN} TN_{t-i} + CN_t, \quad (1b)
\]

\[
TT_t = a^{TT} + \sum_{i=1}^{n} b_i^{TT} CT_{t-i} + \sum_{i=0}^{n-1} c_i^{TT} CT_{t-i} \\
+ \sum_{i=0}^{n} d_i^{TT} TT_{t-i} + \sum_{i=0}^{n} e_i^{TT} TN_{t-i} + TT_t, \quad (1c)
\]

\[
TN_t = a^{TN} + \sum_{i=0}^{n-1} b_i^{TN} CT_{t-i} + \sum_{i=0}^{n-1} c_i^{TN} CN_{t-i} \\
+ \sum_{i=0}^{n} d_i^{TN} TT_{t-i} + \sum_{i=1}^{n} e_i^{TN} TN_{t-i} + TN_t, \quad (1d)
\]

where \(TN_t \) (\(CN_t\)) is the TGE (CBT) nontrading return, \(TT_t \) (\(CT_t\)) is the TGE (CBT)
trading return, and the last term is the mandatory error term. The key to the

\(^6\) Because trading and nontrading returns are by construction 'interrupted' times series, the conventional
initial test for a unit root in their respective price series is not possible. However, separate ADL- and PP
tests for open and close prices indicate that these price series contain a unit root and that the returns
based on these series are stationary.
mneumonic labeling is that the first letter of a variable's symbol indicates the market (T or C), and the second letter denotes the type of return (N or T). For example, TN represents the TGE's nontrading return, and CT identifies the CBT's trading return.

This VAR system takes into account the trading time differences as well as any feedback relationships between the markets. Since CBT trading starts after the close of the TGE, for any given calendar date the TGE trading return is known in the US. Thus, for example, a zero subscript for $TT$ in Eq. (1a) does not indicate a possible contemporaneous relationship between $TT$ and $CT$. However, CBT trading time covers a portion of TGE nontrading time, resulting in a quasi-contemporaneous relation between $CT$ and $TN$, and vice versa. This has important implications for price spillover, since contemporaneous behavior implies a feedback relationship. Thus, the relationship between the trading return in one market and the nontrading return in the other market cannot strictly be considered a spillover. Nevertheless, a spillover can exist, for example, between CBT trading return and the open price of TGE, since the CBT opens after the TGE closes.

To allow for error terms which are heteroskedastic and autocorrelated, the covariance matrix of each equation in the VAR model is estimated by the generalized method of moments (GMM, Hansen, 1982) routine provided by SAS. The robust Wald test statistic to test the null hypothesis that there is no price spillovers is defined as

$$ (R^{\prime} \theta^j) [R^{\prime} \Omega^j (R^j)^{-1}]^{-1} (R^{\prime} \theta^j), $$

where $R$ is the $n \times (4n + 1)$ restriction matrix, and $\Omega$ is the heteroscedasticity- and autocorrelation-consistent covariance matrix of the $(4n + 1)$ coefficient vector $\theta^j$ for markets $j = CT, CN, TT, TN$.

Table 4 presents the robust Wald tests for the null hypothesis that there are no price spillovers from one market to another and from trading (nontrading) time to

<table>
<thead>
<tr>
<th>Market</th>
<th>Equation</th>
<th>Dependent variable</th>
<th>Restricted coefficient values for</th>
<th>Robust Wald statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>CT</td>
<td>CN</td>
</tr>
<tr>
<td>CBT</td>
<td>Eq. (1a)</td>
<td>CT</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CBT</td>
<td>Eq. (1b)</td>
<td>CN</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TGE</td>
<td>Eq. (1c)</td>
<td>TT</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TGE</td>
<td>Eq. (1d)</td>
<td>TN</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TGE</td>
<td>Eq. (1d)</td>
<td>TN</td>
<td>0*</td>
<td></td>
</tr>
</tbody>
</table>

With the exception of the restriction marked with an asterisk, the restrictions are for all $i$. Thus, the Wald test for null hypothesis that there are no price spillovers from one market to another and from trading (nontrading) time to nontrading (trading) time in the same market is $\chi^2(9)$. For the restriction with the asterisk, $i = 0$. In this case, the Wald test for the null hypothesis that there is no price spillover from one market time segment to another is $\chi^2(1)$ distributed. The heteroskedasticity- and autocorrelation consistent covariance matrix used in the Wald test is derived from GMM (Hansen, 1982).
nontrading (trading) time in the same market. Also presented are the relevant coefficient restrictions. By way of an example, consider CBT trading returns. Eq. (1a) is estimated as specified (unrestricted) and then re-estimated forcing \( c_i^{CT} = d_i^{CT} = e_i^{CT} = 0 \) for all \( i \) (restricted). If the unrestricted version does not provide additional explanatory power, the null hypothesis is not rejected. In all cases, the number of lags in the unrestricted model is three. Results are qualitatively the same for one and five lags. Three lags were chosen on the basis of a log-likelihood ratio test.

A review of Table 4 indicates that in all but one instance (TGE nontrading returns) the null hypothesis is not rejected, thereby indicating the lack of price spillovers in these cases. To investigate the exception, several other restrictions were specified and tested. The only restriction ‘package’ which resulted in a significant Wald statistic was \( b_0^{NT} = 0 \), indicating that CBT trading returns impact TGE nontrading returns. On the surface this result appears curious since there is no price spillover from CBT trading returns to TGE trading returns. However, as explained in Section 2, the TGE uses a clearing system which produces equilibrium prices for each session. The key insight is that the true TGE price changes continuously as the information is generated by the CBT; however, prices changes are observed only when transactions occur. The trading system employed by the TGE makes it impossible to observe how the accumulated overnight information is incorporated into prices because transactions occur only at equilibrium prices. Provisional prices collected from traders reflect differences in opinions of market participants, but no transactions occur at those prices and they are adjusted until an equilibrium price, which presumably reflects full information, is reached. Thus, no price spillover is observed to trading returns.

4. Testing for volatility spillover

In this section, volatility spillovers between the TGE and CBT are examined. Volatility is proxied by the square of unexpected trading and nontrading returns. Similar to the approaches in Booth et al. (1996a) and Huang et al. (1996) the residuals are extracted from Eqs. (1a), (1b), (1c) and (1d) and the following multivariate VAR model is established

\[
CT^2_i = a^{CT} + \sum_{i=1}^{n} \beta_i^{CT} CT_{t-i} + \sum_{i=0}^{n-1} \gamma_i^{CT} CN^{2}_{t-i} + \sum_{i=0}^{n-1} \delta_i^{CT} TT^{2}_{t-i} + \sum_{i=0}^{n-1} \epsilon_i^{CT} TN^{2}_{t-i} + \epsilon_t,
\]  

\( (3a) \)

\[
CN^2_i = a^{CN} + \sum_{i=1}^{n} \beta_i^{CN} CT_{t-i} + \sum_{i=1}^{n} \gamma_i^{CN} CN^{2}_{t-i} + \sum_{i=0}^{n-1} \delta_i^{CN} TT^{2}_{t-i} + \sum_{i=1}^{n} \epsilon_i^{CN} TN^{2}_{t-i} + \epsilon_t,
\]  

\( (3b) \)
where $CT$, $CN$, $TT$ and $TN$ are defined in Eqs. (1a), (1b), (1c) and (1d), respectively, and the last term in each equation serves as the error term.7

Each equation in the VAR model with $n$ lags is estimated by GMM and robust Wald statistics are calculated as in Section 3. Results of the Wald tests are provided in Table 5 and are calculated for $n=3$. The test statistics indicate that the same relationships found for price spillovers also hold for volatility spillovers. That is, only the null hypothesis that there is no volatility spillover from CBT trading time to TGE nontrading time is rejected. In other words, CBT trading-time volatility significantly affects TGE nontrading volatility but, as in the price spillover analysis, this volatility spillover is absorbed during the opening auction.

However, it should be noted that this finding may be just a statistical artifact, since volatility is measured as the square of returns and a contemporaneous price relationship exists between CBT trading time and TGE nontrading time. To investigate this possibility, variances of trading and nontrading returns are calculated for the two markets. By comparing volatilities when the markets are open and closed, the period in which the relevant information for each market is produced can be

### Table 5
Volatility spillover restrictions and robust Wald tests

<table>
<thead>
<tr>
<th>Market</th>
<th>Equation</th>
<th>Dependent variable</th>
<th>Restricted coefficient values for</th>
<th>Robust Wald statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$CT$</td>
<td>$CN$</td>
</tr>
<tr>
<td>CBT</td>
<td>Eq. (3a)</td>
<td>$CT^2$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CBT</td>
<td>Eq. (3b)</td>
<td>$CN^2$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TGE</td>
<td>Eq. (3c)</td>
<td>$TT^2$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TGE</td>
<td>Eq. (3d)</td>
<td>$TN^2$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TGE</td>
<td>Eq. (3d)</td>
<td>$TN^2$</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

With the exception of the restriction marked with an asterisk, the restrictions are for all $i$. Thus, the Wald statistic for the null hypothesis that there are no volatility spillovers from one market to another and from trading (nontrading) time to nontrading (trading) time in the same market is $\chi^2(9)$. For the restriction with the asterisk, $i=0$. In this case, the Wald statistic for the null hypothesis that there is no volatility spillover from one market time segment to another is $\chi^2(1)$ distributed. The heteroskedasticity- and autocorrelation-consistent covariance matrix used in the Wald test is derived from GMM (Hansen, 1982).

7 Since the dependent variables are squared regression residuals, they should not contain a unit root. Indeed, ADF and PP tests confirm this assertion.
inferred, since, according to Ross (1989), the variance of returns is equivalent to the rate of information flow. Conventional wisdom suggests that trading time variances are greater than nontrading time variances because information is released through trading. As reported in Table 3, the variance of non-trading returns (0.67) is greater than the variance of trading returns (0.65), but not significantly so (p-value = 0.35) for the CBT. In contrast, the TGE nontrading return variance (0.85) is significantly greater (p-value < 0.01) than the variance of its trading returns (0.58). This is consistent with the notion that the information released through CBT trading is reflected in TGE nontrading returns.

5. Concluding remarks

The empirical analysis suggests that international corn futures markets operate efficiently and that the CBT is the dominant market in the information mechanism. The underlying cash crop of the two futures contracts is grown in the US and is subject to US weather conditions and government regulations. Relevant information is produced during the trading hours of the CBT, and is transmitted to the TGE when the TGE is closed for trading. This information is incorporated into the TGE price during the TGE’s opening auction, which is used to determine an equilibrium price prior to the start of trading. In this respect, these results are consistent with those of Craig et al. (1995), who report that Japanese Nikkei futures traded in the US provide complete information about contemporaneous overnight Japanese returns. Similarly, Booth et al. (1996b) document that relevant information for Nikkei futures contracts is revealed during Tokyo and Singapore trading hours but not during Chicago trading hours. Moreover, Tse et al. (1996) report that relevant information for Eurodollar futures contracts trading in Singapore is produced during the trading hours of the US and London markets. Moreover, since TGE prices reflect corn-specific fundamental news, TGE contracts are suitable for hedging. This may be particularly important for Japanese corn importers, who collectively rank among the largest importers of US corn, since TGE contracts not only can be used to hedge price risk but also freight and foreign exchange rate risk.

Acknowledgements

We are grateful to Masahiro Yamashita of the Tokyo Grain Exchange, who not only provided the data but also commented on our findings with insightful suggestions at various stages of this study. Also appreciated are the comments given by

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8 See, for example, Fama (1965) and French and Roll (1986) for the US stock market, Barclay et al. (1990) for the Japanese stock market, and Booth and Chowdhury (1996) for the German stock market.

9 On a variance per trading hour basis, the relationship is not as dramatic. However, the ratio of trading to nontrading variances is substantially larger for the CBT than the TGE.
the participants of the 1996 International Symposium on Forecasting in Istanbul, especially those of Craig MacKinlay.

References


