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Arbitrage Relation in the Corn Futures Prices of Japan and US*

By

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Abstract

This paper aims to analyze empirically how the price of commodity futures market in Japan is related to an overseas futures price of the same commodity. First, whether the arbitrage activities between the Tokyo Grain Exchange and the Chicago Board of Trade work with respect to corn futures is examined. After the usual statistical test on the arbitrage relation hypothesis among the coefficients of the logarithmic TGE price regression on the logarithmic CBOT price and forward exchange rate, this paper uses data of unit transportation cost, which has been neglected so far. By using the C&F premium, the theoretical arbitrage value of the imported corn price can be directly compared with the TGE corn price.

Key Words

Commodity futures, Transportation cost, Arbitrage, Corn

1. INTRODUCTION

It is a purpose of this paper to analyze empirically how the price of the commodity futures market in Japan is related to an overseas futures price of the same commodity. The large majority of listed goods in the commodity futures market in Japan such as soybean, corn, coffee, raw sugar, rubber, gasoline, and kerosene are import commodities or their processing goods. In that case, are the Japanese futures prices simply the reflex of overseas futures prices (converted into yen) as often said? On the contrary, is it true that participants in Japanese market are forming an original futures price with their anticipation on the future spot price under the foreign exchange rate risk?

The one to bring an intimate relation between prices of two or more markets is the arbitrage. The price of two markets will become the same through the arbitrage trading if there is a difference between prices when one commodity is traded in two

*This paper is a summary of the research conducted by "Economic behavior under the uncertainty" research project of the Keio Economic Observatory in Keio University. In this analysis, the contribution of Mr. Rokuro Sasaya of the Tokyo Grain Exchange is especially large. He taught the authors the actual business custom of the corn deal and did the input work of a large amount of C&F premium data.

The data gathering was also assisted by Mr. Morihiro Yamauchi of the Tokyo Grain Research Association. Moreover, the authors wish to express our gratitude for having gotten a profitable comment and teaching from the participants in the Exchange Problem Symposium held by the Japan Commodity Exchanges Association.

neighboring markets. However, the sameness of the quality of the commodity of each market, the lot size, the terms of delivery, and the currency, etc. is required for it. The price might be different within the range of the unit transportation cost between markets when two markets are located in the remote places. If the difference of two prices exceeds unit transportation cost, arbitrage activity will take place until the observed price of each place differ by exactly the unit transportation cost.

With regard to this, Spiller and Huang (1986) developed a method to analyze prices in separate regions considering transportation cost. They expressed the equation of *autarky* prices for two regions at time t as $P_t^{1A}=\pi^1+\varepsilon_t^1$ and, $P_t^{2A}=\pi^2+\varepsilon_t^2$, where π^i is the constant mean and ε_t^i represents random shock to each market. Let P_t^1, P_t^2 be actual prices and C_t be unit transportation cost. If $|P_t^{1A}-P_t^{2A}|<C_t$, no profitable arbitrage opportunities exist, and $P_t^1=P_t^{1A}$ and $P_t^2=P_t^{2A}$ will hold. However, if the autarky price difference exceeds C_t, the product goods will be transported until the prices differ by exactly C_t. As the result, the markets are integrated, and $P_t^2-P_t^1=C_t$, where prices are assumed to be the higher in region 2. Here, transportation cost was modeled as a random variable with constant mean C: $C_t=C+v_t$. Then, the probability of no arbitrage opportunities between two regions becomes constant: $\lambda=Pr\{P_t^{2A}-P_t^{1A}<C+v_t\}$. Spiller and Huang estimated C and λ using a maximum likelihood method, which is called the switching regression model. Sexton, King and Carman (1991) extended this Spiller and Huang methodology to analyze the U.S. celery market. Since production is concentrated in a few regions, they proposed a similar switching regression model with three regimes: efficient arbitrage, shortage and glut. In contrast to the above papers, since our paper directly uses actual transportation costs data, it is not needed to rely on this switching regression.

Low, Muthuswamy and Webb (1999) analyzed the arbitrage relation of the futures prices of sugar and soybean between the Manila International Futures Exchange (MIFE) and the Tokyo Grain Exchange (TGE). As their paper is the foregoing research for our present paper, their results will be explained in a little detail in the following. Both MIFE and TGE adopt the itayose-hoh auction, or a single fixed-price auction. Each session of auction of two exchanges is held almost at the same time zone. They proposed the following expressions as the arbitrage relation between the futures prices of TGE and MIFE based on a traditional no arbitrage theory.

$$F_t^T=F_t^M W_t^{JP} H_t.$$

Here, F_t^T denotes futures price of MIFE at time t, F_t^M the futures price of TGE, W_t^{JP} the forward exchange rate (yen/peso) and H_t the transportation cost and others. H_t is assumed to be constant in the short-run. Taking the logarithm of both sides of the expression above, and taking differences, they obtain

$$\Delta f_t^T=\Delta f_t^M+\Delta w_t^{JP}.$$

Here, $f_t^T=\ln F_t^T$, $f_t^M=\ln F_t^M$, $w_t^{JP}=\ln W_t^{JP}$. Taking differences, logarithmic value $h_t=\ln H_t$ can be deleted. Therefore, to examine the arbitrage relation between MIFE and TGE, the regression

$$\Delta f_t^T=\alpha+\beta_1\Delta f_t^M+\beta_2\Delta w_t^{JP}+\varepsilon_t$$

only has to be measured. The hypothesis which should be tested becomes $\alpha=0$ and $\beta_1=\beta_2=1$. They analyzed data of six contract months from October 1992 through March

1994. The estimated results became the following.
About sugar:

$$\Delta f_t^T = -0.00011 + 0.4208\Delta f_t^M + 0.5132\Delta w_t^{JP}.$$
$$(0.00043) \quad (0.2142) \quad (0.3857)$$

About soybean:

$$\Delta f_t^T = -0.00013 + 0.2522\Delta f_t^M + 0.4786\Delta w_t^{JP}.$$
$$(0.00027) \quad (0.1861) \quad (0.0723)$$

Here, the figures in parentheses are standard error. From these results, though $\alpha=0$ is not rejected, $\beta_1=\beta_2=1$ is rejected. Therefore, they concluded that there were no arbitrage activities between futures prices of MIFE and TGE. The market liquidity of MIFE was so thin that little arbitrage trading with TGE was done. However, because the market liquidity is high in Chicago Board of Trade (CBOT) the arbitrage trading between CBOT and TGE might be done. Then, it was intended to examine whether the arbitrage with an exchange in Chicago works about the commodity of TGE in this paper.

Corn is selected as a commodity for our analysis according to the criterions described in Section 2. After the analysis on the corn in similar way as Low et al. (1999), this paper will use data of unit transportation cost which has been assumed to be constant. By using the C&F premium, which is the transportation cost of corn per bushel from Gulf in U.S. to Japanese harbor, the theoretical value of the imported corn price can be directly compared with the TGE corn price.

In what follows, the arbitrage relation between Japan and U.S. at the corn futures is inspected in Section 2. The case considered for C&F premium is analyzed in Section 3, and the conclusion is described in Section 4.

2. THE CORN FUTURES PRICES OF TGE AND CBOT

First, the commodity for the analysis is selected from the ones listed in TGE. The contract months of the soybean are even-numbered in TGE, though they are odd-numbered months in CBOT. In raw sugar of TGE and sugar of CSCE, there are common odd-numbered contract months. However, these commodities are different in quality. On arabica coffee and robusta coffee, the number of data is insufficient, for they were listed recently in TGE.

Corn is selected as a commodity for the analysis from the following reason. On corn, as shown in Table 1, four odd-numbered contract months (i.e. Mar., May, Jul. and Sep.) are common between CBOT and TGE. The maturity date in CBOT is seven days before the final business day of the delivery month. Besides, the maturity in TGE is the 15th on the previous month of the delivery month. Further, the commodities of two exchanges are almost the same. The standard grade is yellow corn No.3 in TGE, while it is No.2 in CBOT. The rating of No.3 corn of CBOT is lower than No.2 by 1.5 cents per bushel. However, No.2 is assumed to be the same rank to No.3 in TGE. Moreover, the variation of the quality of the standard grade dealt in Chicago is larger than that of the one dealt in Tokyo. Therefore, the difference of the standard grade between

Table 1.
The Terms of Trade of Corn Futures of TGE and CBOT

	TGE	CBOT
Contract Size	100,000 kilograms	5,000 bushel
Contract Month	Jan., Mar., May, Jul., Sep. and Nov. (within a 12 month period)	Mar., May, Jul., Sep. and Dec.
Price Quotation	1000 kilograms (39.368 bushel)	1 bushel
Minimum Price Fluctuation	10 yen	1/4 cent
Maturity Date	15^{th} day of the month preceding the delivery month; if that day is not a business day, then the last trading day is moved up to the nearest business day.	7 days before the final business day of the delivery month
Delivery Period	From the 1st day to the last day of the delivery month	From the 1st business day to the last business day of the delivery month
Standard Grade	No. 3 yellow corn produced in the U.S.A. with less than 15% Moisture	No. 2 yellow at par
Method of Settlement	Physical delivery. CIF Japan	
Delivery Points	The piers of Kashima, Chiba, Kawasaki or Yokohama ports	

TGE and CBOT can be disregarded. In addition, the sample period can be long enough.

We analyze daily closing prices of corn futures of TGE and CBOT. Sample period covers contract months of Mar., May, Jul. and Sep. every year from 1996 to 1999, 16 contract months in total. Figure 1 and 2 show the movement of the corn futures prices of nearby delivery month in Tokyo and Chicago respectively. The unit of the vertical axis is yen per ton in Figure 1, and cent per bushel in Figure 2.

The trend of corn prices during this period was as follows. The price reached historic high by the meat demand expansion mainly in Asia at 1996, and inventory-sales ratio also fell to 5%, the lowest level in history. Afterwards, the demand and supply relaxed because the demand declined by the financial crisis in Asia and the production expanded. The spot price per bushel decreased below 2 dollars in 1998, and stopped at 180-cent level, which is the compensation level of the U.S. Government for the farmers. The United States has a 41.5 percent share of corn production in the world in 1998/99, China has a 20.8(%), and Latin America has an 11.0(%), respectively. The production of Brazil and Argentina has expanded rapidly for these several years. The chief producing district of corn in the United States is the Midwest Corn Belt. The crop is held in April, and the harvest is September and October. The weather at the pollination time of the summer time controls the output.

The following notations are used in this paper.

F_t : corn futures closing price of TGE at time t (yen per ton) (actual value in Figure 1),
F_t^* : corn futures closing price of CBOT (cent per bushel) (CBOT in Figure 2),
W_t : forward exchange rate (yen per dollar, Tokyo market),
H_t' : transportation cost (ratio to price of corn futures); $H_t = 1 + H_t'$,
S_t : spot exchange rate closing price (yen per dollar, Tokyo market),
t^* : maturity date of corn futures in TGE,

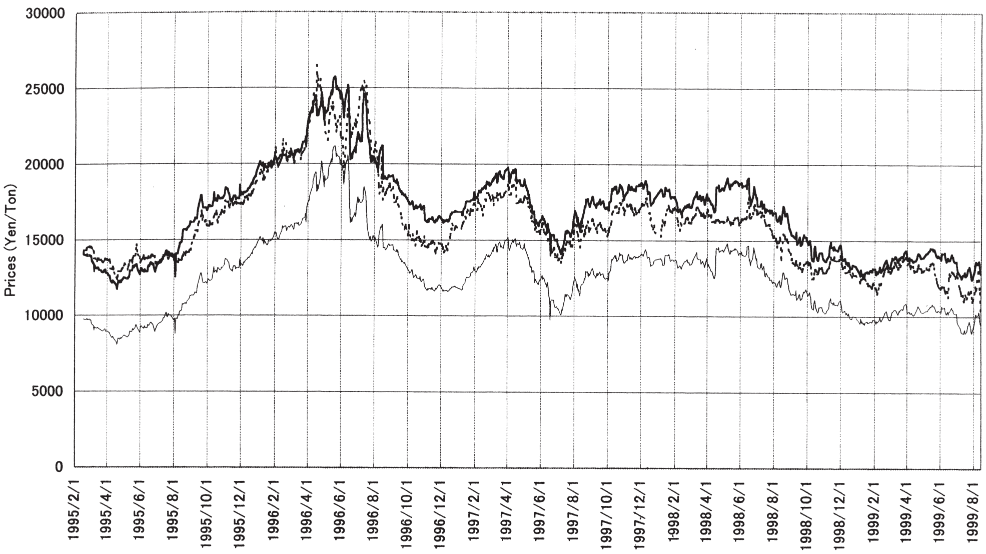

Figure 1. Theoretical and Observed Prices in TGE

The thick solid line represents corn futures prices of nearby delivery month in TGE. The dotted line represents the theoretical prices calculated considering with transportation cost. The thin solid line represents corn futures prices in CBOT converted into yen/ton. The unit of the vertical is yen per ton.

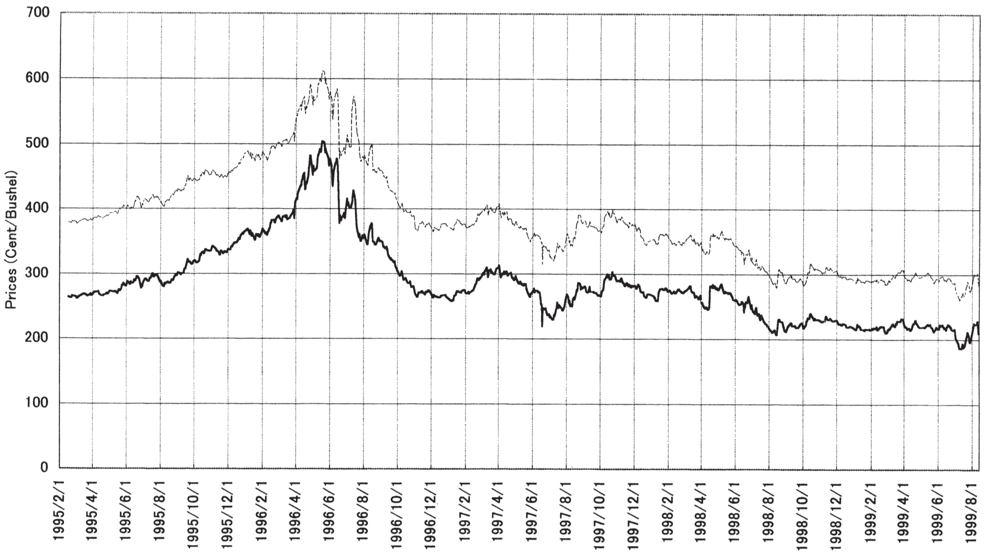

Figure 2. Corn Futures Prices in CBOT

The solid line represents corn futures prices nearby delivery month in CBOT. The dotted line represent the sum of the futures prices and transportation cost (C&F premium). The unit of the vertical is cent per bushel.

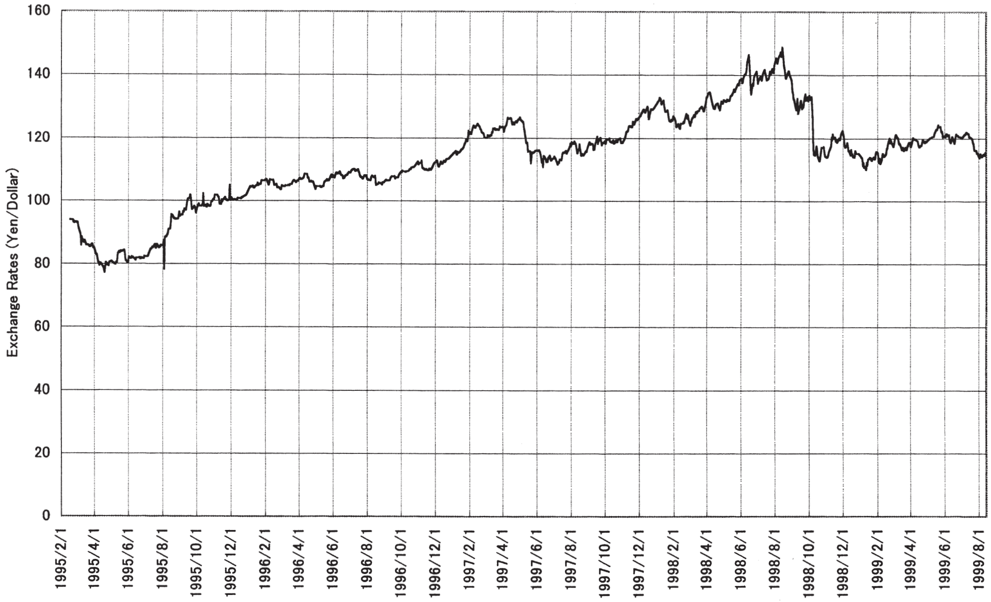

Figure 3. Forward Exchange Rates

The line represents forward exchange rate calculated from foreign exchange forward premium.

g_t : foreign exchange forward premium (annual rate).

In this paper, the forward exchange rates are calculated by $W_t = S_t e^{g_t(t^*-t)/365}$. As the forward premium g_t, 1-month forward premium for maturity at $t^*-t<2$ months and 3 months forward premium for maturity at $t^*-t\geq 2$ months are used. Figure 3 shows the calculated forward exchange rates. By using these notations, if the traditional arbitrage relation exists between the futures prices of TGE and CBOT, we obtain

$$F_t = F_t^* W_t H_t.$$

Taking the logarithm of both sides, it follows

$$f_t = f_t^* + w_t + h_t,$$

where $f_t = \ln F_t$, $f_t^* = \ln F_t^*$, $w_t = \ln W_t$, $h_t = \ln H_t$. Thus, the regression

$$f_t = \alpha + \beta f_t^* + \gamma w_t + u_t$$

is estimated. Here, h_t is assumed to be a constant value α. In this regression, the hypothesis: $\beta = \gamma = 1$ is tested. The measurement result of this regression is shown in Table 2 in each contract month. The result by poolng all the 16 contract months from March 1996 through September 1999 is

$$\begin{array}{llll} f_t = 0.926300 + 0.818369 f_t^* + 0.872530 w_t & n=3809, & R^2=0.767276. \\ \quad (0.078735) \quad (0.007870) \quad (0.007885) & \mathrm{DW}=0.06905 & \end{array}$$

The estimated values of β and γ are near unity in some contract months in Table 2. However, there can be a strong positive auto correlation in the residual term because Durbin-Watson ratios[1] are near zero. If the explained variable and the explanatory

Table 2.
Measurement Results of Regression: $\alpha+\beta f_t^*+\gamma w_t$ and Unit-Root Test

Contract	α	β	γ	$\bar{R}^2$	DW	n	Unit-Root
Mar-96	2.5105	0.7902	0.5769	0.9391	0.9391	241	
	(0.1184)	(0.0396)	(0.0444)				
May-96	1.9057	1.2326	0.1467	0.9715	0.3353	241	
	(0.0868)	(0.0342)	(0.0421)				
Jul-96	2.1042	0.8059	0.6453	0.9182	0.1373	241	f[**]
	(0.1924)	(0.0373)	(0.0712)				
Sep-96	-1.5282	1.6742	0.6281	0.8527	0.1385	242	f^*[*]
	(0.5020)	(0.1750)	(0.0682)				
Mar-97	3.9848	0.8763	0.1596	0.7164	0.0987	238	
	(0.7605)	(0.0500)	(0.1117)				
May-97	4.9169	0.8045	0.0463	0.6483	0.0869	238	
	(0.2898)	(0.0391)	(0.0283)				
Jul-97	-0.8425	1.0659	0.9475	0.8377	0.2052	238	
	(0.3694)	(0.0305)	(0.0506)				
Sep-97	0.8949	0.9208	0.7588	0.7687	0.3166	237	
	(0.3397)	(0.0345)	(0.0490)				
Mar-98	0.5271	0.8740	0.8845	0.8853	0.4486	236	
	(0.2148)	(0.0359)	(0.0380)				
May-98	0.6086	0.7932	0.9601	0.8784	0.3370	238	
	(0.2327)	(0.0368)	(0.0308)				
Jul-98	1.5261	0.8826	0.6586	0.8278	0.3169	236	
	(0.2490)	(0.0380)	(0.0281)				
Sep-98	4.9206	0.4908	0.4191	0.4536	0.2603	236	
	(0.3806)	(0.0354)	(0.0416)				
Mar-99	1.7628	0.7358	0.7802	0.9571	0.3117	237	
	(0.1104)	(0.0143)	(0.0197)				
May-99	2.4299	0.7206	0.6594	0.9249	0.2163	237	
	(0.1323)	(0.0246)	(0.0253)				
Jul-99	2.1740	0.8162	0.6018	0.8469	0.1509	237	f^*[*]
	(0.2071)	(0.0402)	(0.0340)				
Sep-99	1.1244	0.9426	0.6791	0.8095	0.4358	236	
	(0.2676)	(0.0336)	(0.0343)				

Notes: Standard errors are in parentheses. The Column "Unit-Root" shows the variables for which the null hypothesis is rejected, hence indicating no presence of unit-roots using augmented Dickey-Fuller tests. Significance at 10% level is indicated by*, and at the 5% level by**.

variable are integrated variables of the first order $I(1)$, the spurious regression might be observed. In order to estimate the order of the integration of both futures price of TGE and CBOT and the forward exchange rate, the augmented Dickey-Fuller tests of a unit-root are applied to f, f^* and w. The last column of Table 2 shows the variable to which $I(1)$ null is rejected. These results are also shown in Table 8 along with the case of the variables introduced in the next section. These results show that f, f^* and w are $I(1)$ at most contract months.

However, it is said that the explained variable and the explanatory variables are cointegrated if the disturbance term is $I(0)$ even if the explained variable and the explanatory variables are $I(1)$. In such a case, there is no possibility of the spurious

[1] $\mathrm{DW}\equiv\sum_{t=2}^{n}(\hat{u}_t-\hat{u}_{t-1})^2/\sum_{t=2}^{n}\hat{u}_t^2\approx 2(1-r)$, where r is the first order serial correlation coefficient ($r=\sum_{t=2}^{n}\hat{u}_t\hat{u}_{t-1}/\sum_{t=1}^{n}\hat{u}_t^2$).

Table 3.
Measurement Results of Regression: $\Delta f_t = \alpha + \beta \Delta f_t^* + \gamma \Delta w_t$

Contract	α	β	γ	$\bar{R}^2$	DW	n
Mar-96	0.00135	0.2066	0.2326	0.0926	1.8944	240
	(0.00077)	(0.0783)	(0.0511)			
May-96	0.00165	0.2292	0.3891	0.1031	1.9017	240
	(0.00085)	(0.0758)	(0.0860)			
Jul-96	0.00167	0.2674	0.1159	0.0409	1.5502	240
	(0.00113)	(0.0835)	(0.0802)			
Sep-96	0.00051	0.2318	0.2483	0.0374	1.6763	241
	(0.00129)	(0.1508)	(0.0867)			
Mar-97	-0.00064	0.2332	0.3915	0.0460	2.0764	237
	(0.00109)	(0.0753)	(0.2089)			
May-97	-0.00055	0.2434	0.0076	0.0425	2.1758	237
	(0.00108)	(0.0744)	(0.0051)			
Jul-97	-0.00098	0.2698	0.5651	0.0991	2.2268	237
	(0.00099)	(0.0768)	(0.1442)			
Sep-97	-0.00083	0.1031	0.7908	0.1124	2.1630	236
	(0.00111)	(0.0631)	(0.1479)			
Mar-98	-0.00006	0.2588	0.6474	0.1446	2.2343	235
	(0.00103)	(0.0740)	(0.1191)			
May-98	-0.00008	0.2455	0.5746	0.1515	2.1790	237
	(0.00093)	(0.0703)	(0.1013)			
Jul-98	0.00041	0.2030	0.3991	0.0856	2.0688	235
	(0.00094)	(0.0736)	(0.0956)			
Sep-98	-0.00058	0.2001	0.2989	0.0575	2.1962	235
	(0.00087)	(0.0690)	(0.0916)			
Mar-99	-0.00078	0.1510	0.5209	0.2927	2.1919	236
	(0.00063)	(0.0511)	(0.0535)			
May-99	-0.00055	0.1813	0.5699	0.3067	2.2809	236
	(0.00066)	(0.0542)	(0.0565)			
Jul-99	-0.00098	0.1894	0.5675	0.2828	2.0671	236
	(0.00070)	(0.0595)	(0.0601)			
Sep-99	-0.00109	0.2104	0.5875	0.1620	1.5087	235
	(0.00099)	(0.0711)	(0.0903)			

Notes: Standard errors are in parentheses.

correlation. Then, taking differences, we obtain

$$\Delta f_t = \alpha + \beta \Delta f_t^* + \gamma \Delta w_t + u_t.$$

Here α is added for convenience and u_t is redefined for Δu_t. Table 3 shows the measurement result of the regression taken difference. The hypothesis: $\beta = \gamma = 1$ is rejected at most contract months. The measurement result by pooling all the 16 contract months from March 1996 through September 1999 is

$$\underset{(0.000239)}{\Delta f_t = -0.000143} + \underset{(0.018456)}{0.212808} \Delta f_t^* + \underset{(0.022707)}{0.412091} \Delta w_t \quad n = 3793,\ R^2 = 0.105203. \quad \mathrm{DW} = 2.04307$$

As a result, the hypothesis: $\beta = \gamma = 1$ is rejected.

3. TRANSPORTATION COST

In the previous section, the transportation cost is assumed to be a constant share H_t' of the price. However, the transportation cost is actually calculated per unit volume. Transportation cost from the Gulf, where the elevators of corn in the United States site, to the ports in Japan is called C&F premium. In addition, there are the import charges: interest rate, bank charge, the loss risk fee, the stevedorage, and the land fare, etc. Since these charges are borne by the purchaser in case of corn, they are not included in the transportation cost here.

The C&F premium for each time of shipment is made public every trading day[2]. The premium whose time of shipment is the nearest to the delivery month is used in this paper. For instance, if the contract month is March, the last trading day in TGE is around February 15. Time required to transport corn from the United States to Japan is one and a half months[3]. Thus, if they ship corn in the middle of Feb., it is in time for delivery during March. Therefore, we use the data of the C&F premium whose time of shipment is February. However, if it is long before Feb., the premium whose time of shipment is Feb. is not dealt yet. In such cases, the data whose time of shipment is nearest as possible to Feb. are used. Figure 4 shows the part of these premiums selected by this criterion, corresponding to the prices shown in Figure 1. Moreover, the prices that the C&F premiums are added to the dollar denominated prices in CBOT are shown in Figure 2. The size of transportation cost, as shown in Figure 2, is not negligible compared with the corn prices.

Let C_t be the C&F premium (cent/bushel), J_t be the theoretical futures price in

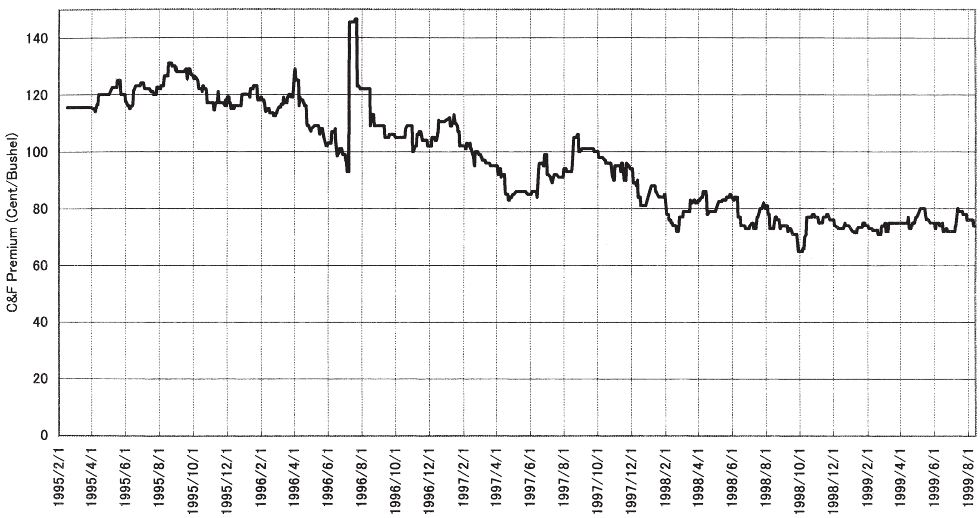

Figure 4. C&F Premium

The line represents C&F premium selected by the criterion in Section 4.

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[2]The C&F premium is from "Trade Daily Newspaper, fodder version" published by Jiji Press Ltd.

[3]Around 30 to 35 days are required from New Orleans to Japan with a high-speed ship by way of The Panama Canal.

Table 4.
Measurement Results of Regression: $f_t = \alpha + \beta q_t + \gamma w_t$ and Unit-Root Test

Contract	α	β	γ	$\bar{R}^2$	DW	n	Unit-Root
Mar-96	1.5164 (0.2072)	0.6361 (0.0467)	0.6986 (0.0523)	0.9090	0.1242	241	
May-96	-1.0001 (0.1854)	1.2432 (0.0487)	0.2041 (0.0566)	0.9508	0.2210	241	
Jul-96	-0.3029 (0.1820)	0.9504 (0.0397)	0.5560 (0.0681)	0.9288	0.1787	241	f[**]
Sep-96	-2.8106 (0.4157)	0.6017 (0.0600)	1.7099 (0.1601)	0.8595	0.1740	242	q[*]
Mar-97	-2.2858 (0.8897)	1.0155 (0.0469)	0.8845 (0.1200)	0.7819	0.1793	238	
May-97	-3.2432 (0.5201)	1.0133 (0.0313)	1.0930 (0.0674)	0.8300	0.2000	238	
Jul-97	-3.2300 (0.4186)	0.9278 (0.0259)	1.2297 (0.0545)	0.8446	0.2169	238	
Sep-97	-1.9050 (0.3555)	0.8767 (0.0272)	1.2297 (0.0536)	0.8281	0.4420	237	
Mar-98	-2.1255 (0.3862)	0.7292 (0.0405)	1.3087 (0.0431)	0.8303	0.3332	236	
May-98	-1.2551 (0.3400)	0.5943 (0.0310)	1.3386 (0.0355)	0.8587	0.3123	238	
Jul-98	-2.2447 (0.3649)	0.8472 (0.0336)	1.1401 (0.0321)	0.8471	0.4263	236	
Sep-98	1.5302 (0.5864)	0.5610 (0.0384)	0.8151 (0.0638)	0.4802	0.3141	236	
Mar-99	1.1902 (0.0981)	0.6656 (0.0108)	0.7191 (0.0168)	0.9695	0.4647	237	
May-99	1.9706 (0.1218)	0.6150 (0.0177)	0.6348 (0.0238)	0.9433	0.3101	237	
Jul-99	1.5453 (0.2107)	0.7045 (0.0313)	0.5840 (0.0319)	0.8663	0.1922	237	
Sep-99	-0.8867 (0.3256)	0.9246 (0.0328)	0.7587 (0.0347)	0.8117	0.4536	236	

Notes: Standard errors are in parentheses. The column "Unit-Root" shows the variables for which the null hypothesis is rejected, hence indicating no presence of unit-roots using augmented Dickey-Fuller tests. Significance at 10% level is indicated by*, and at the 5% level by**.

TGE (yen/ton) and $Q_t = F_t^* + C_t$. Converting ton into bushel by using the relation: one ton$=$39.368 metric bushel, and cent into dollar, it follows,

$$J_t = 0.39368 Q_t W_t.$$

Thus, if the price in TGE is equal to this theoretical value, the relation

$$F_t = 0.39368 Q_t W_t.$$

holds. Taking the logarithm of both sides, the regression to be measured is

$$f_t = \alpha + \beta q_t + \gamma w_t + u_t,$$

where $q_t = \ln Q_t$. Table 4 shows the measurement results for each of 16 contract months. Table 6 shows the results of the regressions by pooling four contract months for each year, by pooling four years data for each contract month, and by pooling all data. Results of the augmented Dickey-Fuller tests of a unit-root show that f, q and w

Table 5.
Measurement Results of Regression: $\Delta f_t = \alpha + \beta \Delta q_t + \gamma \Delta w_t$

Contract	α	β	γ	$\bar{R}^2$	DW	n
Mar-96	0.00126	0.1302	0.2345	0.0807	1.8816	240
	(0.00078)	(0.0775)	(0.0514)			
May-96	0.00173	0.1915	0.3908	0.0979	1.8699	240
	(0.00085)	(0.0689)	(0.0862)			
Jul-96	0.00184	0.2164	0.1143	0.0328	1.5274	240
	(0.00113)	(0.0755)	(0.0805)			
Sep-96	0.00067	0.1260	0.2586	0.0299	1.6240	241
	(0.00129)	(0.0502)	(0.1509)			
Mar-97	-0.00053	0.1742	0.4000	0.0399	2.0522	237
	(0.00109)	(0.0614)	(0.2096)			
May-97	-0.00092	0.2048	0.5404	0.0596	2.2122	237
	(0.00108)	(0.0668)	(0.2008)			
Jul-97	-0.00090	0.2405	0.5626	0.0968	2.2073	237
	(0.00100)	(0.0703)	(0.1444)			
Sep-97	-0.00080	0.1018	0.7896	0.1139	2.1641	236
	(0.00111)	(0.0578)	(0.1478)			
Mar-98	0.00003	0.1925	0.6308	0.1292	2.1980	235
	(0.00104)	(0.0684)	(0.1203)			
May-98	-0.00006	0.1932	0.5703	0.1381	2.1516	237
	(0.00094)	(0.0667)	(0.1021)			
Jul-98	0.00050	0.1778	0.3941	0.0824	2.0524	235
	(0.00095)	(0.0683)	(0.0957)			
Sep-98	-0.00049	0.1764	0.2981	0.0506	2.1706	235
	(0.00087)	(0.0683)	(0.0922)			
Mar-99	-0.00083	0.1074	0.5208	0.2842	2.1605	236
	(0.00063)	(0.0443)	(0.0539)			
May-99	-0.00063	0.1103	0.5665	0.2907	2.2054	236
	(0.00067)	(0.0464)	(0.0574)			
Jul-99	-0.00105	0.1036	0.5644	0.2647	1.9694	236
	(0.00071)	(0.0509)	(0.0610)			
Sep-99	-0.00107	0.2090	0.5930	0.1665	1.7055	235
	(0.00098)	(0.0964)	(0.0902)			

Notes: Standard errors are in parentheses.

are non-stationary at most contract months like the previous section. Table 4 and 8 show the results of the unit-root tests.

Next, taking differences, the regression

$$\Delta f_t = \alpha + \beta \Delta q_t + \gamma \Delta w_t$$

is estimated. Table 5 shows the results of each contract month. Table 7 shows the case of the pooled data in the same way as Table 6. Comparing Table 2 and 4, the coefficient of q in case the transportation cost is added is not so different from the coefficient of f^* in case the transportation cost is not considered. Moreover, the hypothesis: $\beta = \gamma = 1$ is rejected similarly as the previous section. As shown in Table 8, no cointegration relation exists except three contract months.

Considering the time difference between Tokyo and Chicago, it might be necessary to use the price of CBOT at the day before the corresponding day in TGE when assuming that the price of CBOT affects that of TGE. Thus, altering the price of CBOT into the one at the day before, the similar analysis is attempted. Table 9 shows

Table 6.
Measurement Results of Regression: $f_t = \alpha + \beta q_t + \gamma w_t$ (Pooled Data)

Contract	α	β	γ	$\bar{R}^2$	DW	n
96.3-9	-0.2678	0.8347	0.7526	0.9023	0.1262	965
	(0.1080)	(0.0243)	(0.0356)			
97.3-9	-2.4060	0.9338	1.0470	0.8318	0.2295	951
	(0.2502)	(0.0143)	(0.0338)			
98.3-9	-1.1038	0.6818	1.1686	0.7625	0.2595	946
	(0.2073)	(0.0165)	(0.0214)			
99.3-9	1.4105	0.6831	0.6464	0.9210	0.3028	947
	(0.0774)	(0.0102)	(0.0129)			
Mar (96-9)	0.5338	0.7388	0.7405	0.8759	0.1349	952
	(0.1179)	(0.0134)	(0.0134)			
May (96-9)	0.4436	0.7370	0.7624	0.8844	0.1246	954
	(0.1198)	(0.0086)	(0.0146)			
Jul (96-9)	0.3096	0.7489	0.7700	0.9114	0.1448	952
	(0.1187)	(0.0076)	(0.0159)			
Sep (96-9)	-0.7265	0.8211	0.8802	0.9207	0.2306	951
	(0.1434)	(0.0081)	(0.0203)			
96-99. (3-9)	0.2162	0.7565	0.7801	0.8925	0.1439	3809
	(0.0626)	(0.0043)	(0.0080)			

Notes: Standard errors are in parentheses.

Table 7.
Measurement Results of Regression: $\Delta f_t = \alpha + \beta \Delta q_t + \gamma \Delta w_t$ (Pooled Data)

Contract	α	β	γ	$\bar{R}^2$	DW	n
96.3-9	0.00131	0.2430	0.2264	0.0592	1.7116	961
	(0.00051)	(0.0472)	(0.0376)			
97.3-9	-0.00092	0.1954	0.6105	0.0802	2.1755	947
	(0.00053)	(0.0355)	(0.0842)			
98.3-9	-0.00013	0.2351	0.4716	0.1141	2.1917	942
	(0.00047)	(0.0358)	(0.0506)			
99.3-9	-0.00085	0.1842	0.5610	0.2478	1.9921	943
	(0.00038)	(0.0300)	(0.0327)			
Mar (96-9)	-0.00003	0.2222	0.3952	0.1154	2.1260	948
	(0.00045)	(0.0353)	(0.0416)			
May (96-9)	-0.00003	0.2293	0.5261	0.1445	2.1453	950
	(0.00044)	(0.0343)	(0.0475)			
Jul (96-9)	0.00009	0.1820	0.3813	0.0902	1.9559	947
	(0.00050)	(0.0353)	(0.0451)			
Sep (96-9)	-0.00055	0.1653	0.4029	0.0791	1.9371	947
	(0.00054)	(0.0398)	(0.0486)			
96-99. (3-9)	-0.00014	0.2128	0.4121	0.1052	2.0435	3793
	(0.00024)	(0.0185)	(0.0227)			

Notes: Standard errors are in parentheses.

the results from the data taken lag. Table 10 shows the results from the data taken lag and difference. The conclusion is almost the same as that of not taking lag. However, the price of CBOT at the day before affects the price of TGE, because the coefficients are obviously large compared with the case using the Chicago price on that day, especially for the difference regression. In any case of the above-mentioned analysis, the arbitrage relation: theoretical price $J_t =$ actual price F_t does not exist. Figure 1 shows the theoretical prices and the actual prices of nearby delivery month. From this

Table 8.
Results of Unit-Root Test and Cointegration Test

	Unit-Root			Cointegration	
	f_t	q_t	w_t	f_t, q_t, w_t	f_t, q_{t-1}, w_t
Mar-96		*/	/*		
May-96					
Jul-96	**/**				
Sep-96		**/*	**/*		
Mar-97					
May-97					
Jul-97					
Sep-97				**	*
Mar-98					
May-98			/*		
Jul-98					
Sep-98					
Mar-99				*	
May-99				*	*
Jul-99		/*			
Sep-99		**/			

Notes: The column "Unit-Root" shows the variables for which the null hypothesis is rejected, hence indicating no presence of unit-roots. Significance at 10% level is indicated by*, and at the 5% level by**, using "Augmented Dickey-Fuller tests/ Augmented weighted symmetry tests". The column "Cointegration" shows the variables for which the null hypothesis is rejected, hence indicating presence of cointegration. Significance at 10% level is indicated by*, and at the 5% level by**.

figure, in almost periods the theoretical price J_t is higher than the actual price F_t. The reason why the state: $J_t > F_t$ continues is that the arbitrage trading by the transportation of physical corn works only in one direction: from the United States to Japan.

In case of theoretical price $J_t <$ actual price F_t, there exist chances of arbitrage trading as follows. It is fixed to obtain earning of $F_t - J_t$ by the deal of selling futures in TGE, buying futures of the same quantity in CBOT and making the import forward exchange contract. The traders deliver corn in TGE by transporting the corn from the United States. Actually, they buy the corn spot in the United States on around the 15th day of the month preceding the delivery month, and they ship the corn for Japan. In the delivery month, the corn for the long futures contract in CBOT is delivered by the seller's option and they sell the delivered corn. Because the seller decides the date of delivery, the period from buying the corn to selling this corn is about a half or one month. Therefore, profit and loss changes somewhat depending on the fluctuation of the spot price at this period. This corn transported from the United States is delivered to the buyers of futures in TGE at the end of the delivery month.

On the contrary, in case of theoretical price $J_t >$ actual price F_t, such an arbitrage trading by the transportation does not work, because collecting a necessary amount of corn in Japan will raise the purchase price of corn greatly and is not conceivable.

4. CONCLUSION

Summary of the above analysis on corn is as follows.

1) The hypothesis that the arbitrage activities exist between TGE and CBOT is

Table 9.
Measurement Results of Regression $f_t = \alpha + \beta q_{t-1} + \gamma w_t$

Contract	α	β	γ	$\bar{R}^2$	DW	n
Mar-96	1.4671	0.6508	0.6844	0.9120	0.1057	236
	(0.2063)	(0.0470)	(0.0523)			
May-96	-1.169	1.2839	0.1714	0.9533	0.1582	240
	(0.1842)	(0.0483)	(0.0557)			
Jul-96	-0.3477	0.9450	0.5754	0.9297	0.1170	240
	(0.1822)	(0.0393)	(0.0678)			
Sep-96	-2.6325	0.6393	1.6072	0.8649	0.1510	241
	(0.4099)	(0.0588)	(0.1578)			
Mar-97	-2.1291	1.0095	0.8607	0.7789	0.1246	237
	(0.8943)	(0.0472)	(0.1206)			
May-97	-3.3165	1.0114	1.1113	0.8265	0.1440	237
	(0.5269)	(0.0316)	(0.0683)			
Jul-97	-3.2879	0.9270	1.2428	0.8396	0.1718	237
	(0.4271)	(0.0264)	(0.0555)			
Sep-97	-1.9232	0.8638	1.0601	0.8289	0.3867	236
	(0.3538)	(0.0270)	(0.0451)			
Mar-98	-2.3451	0.7642	1.2990	0.8495	0.2866	235
	(0.3642)	(0.0386)	(0.0406)			
May-98	-1.3154	0.6058	1.3328	0.8671	0.2575	237
	(0.3286)	(0.0302)	(0.0343)			
Jul-98	-2.4721	0.8757	1.1421	0.8699	0.3737	235
	(0.3360)	(0.0311)	(0.0295)			
Sep-98	1.6201	0.5601	0.7977	0.4846	0.2614	235
	(0.5810)	(0.0382)	(0.0629)			
Mar-99	1.2252	0.6703	0.7045	0.9742	0.3767	236
	(0.0898)	(0.0100)	(0.0156)			
May-99	1.9921	0.6226	0.6185	0.9495	0.2321	236
	(0.1144)	(0.0169)	(0.0211)			
Jul-99	1.5142	0.7226	0.5627	0.8746	0.1559	236
	(0.2034)	(0.0305)	(0.0311)			
Sep-99	-0.9193	0.9429	0.7374	0.8379	0.3824	235
	(0.2995)	(0.0301)	(0.0324)			

Notes: Standard errors are in parentheses.

rejected by measuring the regression taken differences.

2) According to the measurement of the regression considering the C&F premium and also taking differences, there is no evidence of the traditional arbitrage activities.

3) The price calculated by traditional no arbitrage theory considering the C&F premium always exceeds the actual price in Tokyo at most periods.

From these results, excluding very short periods when theoretical price $J_t <$ actual price F_t, exact arbitrage activities do not exist between futures markets of the corn of TGE and CBOT. Tokyo and Chicago are separated in the distance and prices of corn per weight are low. Thus, the ratio of the transportation cost to the price is large and not negligible. Therefore, unlike asset markets and precious metals markets, the relation of the price of both markets determined by the arbitrage activities is loose. Because of the transportation cost, only the arbitrage activities in one direction: to sell in Tokyo and buy in Chicago are done. Therefore, the arbitrage activities cannot cancel the state in which the actual corn price in Tokyo is below the theoretical price, calculated from price in Chicago including transportation cost.

Table 10.
Measurement Results of Regression: $\Delta f_t = \alpha + \beta \Delta q_{t-1} + \gamma \Delta w_t$

Contract	α	β	γ	$\bar{R}^2$	DW	n
Mar-96	0.00067	0.5427	0.1846	0.2611	1.8845	235
	(0.00070)	(0.0701)	(0.0463)			
May-96	0.00114	0.5022	0.3275	0.2697	1.8913	239
	(0.00076)	(0.0625)	(0.0785)			
Jul-96	0.00101	0.6468	0.0722	0.2878	1.6491	239
	(0.00097)	(0.0661)	(0.0693)			
Sep-96	0.00048	0.2818	0.2447	0.1325	1.6398	240
	(0.00123)	(0.0476)	(0.1431)			
Mar-97	-0.00025	0.4068	0.3262	0.1879	2.1357	236
	(0.00100)	(0.0564)	(0.1922)			
May-97	-0.00067	0.4214	0.6053	0.1855	2.3523	236
	(0.00100)	(0.0619)	(0.1859)			
Jul-97	-0.00072	0.3989	0.6130	0.1762	2.2800	236
	(0.00096)	(0.0674)	(0.1388)			
Sep-97	-0.00057	0.2006	0.7901	0.1514	2.2337	235
	(0.00108)	(0.0565)	(0.1443)			
Mar-98	0.00021	0.4446	0.6333	0.2573	2.2884	234
	(0.00096)	(0.0633)	(0.1113)			
May-98	0.00027	0.4465	0.5881	0.2719	2.2818	236
	(0.00086)	(0.0612)	(0.0937)			
Jul-98	0.00067	0.4825	0.3871	0.2528	2.1341	234
	(0.00086)	(0.0618)	(0.0865)			
Sep-98	-0.00010	0.4377	0.2517	0.1997	2.2393	234
	(0.00080)	(0.0612)	(0.0826)			
Mar-99	-0.00061	0.3013	0.5214	0.4079	2.2436	235
	(0.00057)	(0.0404)	(0.0489)			
May-99	-0.00037	0.3222	0.5666	0.4221	2.2411	235
	(0.00061)	(0.0417)	(0.0513)			
Jul-99	-0.00098	0.2781	0.5816	0.3595	2.0295	235
	(0.00067)	(0.0473)	(0.0571)			
Sep-99	-0.00095	0.4670	0.5776	0.3136	1.8438	234
	(0.00090)	(0.0595)	(0.0814)			

Notes: Standard errors are in parentheses.

The actual price below the theoretical value means that the import traders sell the goods for cheaper price than the sum of buying price and transportation cost in Tokyo. Why do the trading companies import corn though they loose obviously? According to Sasaya (2000), the phenomenon that the price at the place of consumption is lower than that at the place of production can be explained by a kind of short hedging: 'a negative spread increasing trading', which uses skillfully the time lag of decline of the spot prices and the futures prices. Though the futures price quotes the low at off-crop season with the good harvest anticipation, the grain merchants buy the spot goods at the place of production for higher price than the futures and hedge them in the futures market. The news of good harvest lower the futures price further as the harvest is drawing near. However, because the arrival of the spot goods is still a little, the fall of the spot price is not large at the place of consumption. Then, they buy back the futures at that time, and sell off the spot goods for cheaper price than buying. As a result, the grain merchants can get the profit from the futures trading larger than the loss from the spot. This can certainly explain the negative spread phenomenon when the prices fall.

However, as shown in Figure 1, at the time the prices rise, the negative spread is also observed. When large-volume customers like a general trading company buy corn, it seems that they receive some discount. If this discount is larger than the negative spread, the import of corn can bring them a profit.

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