An Empirical Analysis of the Efficiency of the Osaka Rice Market During Japan's Tokugawa Era

SHIGEYUKI HAMORI*
NAOKO HAMORI
DAVID A. ANDERSON

The Dojima Rice Market in Osaka was the first futures market in the world, and an influential role model for modern futures markets. This study examines the efficiency of the original futures market by applying time-series analysis to data on futures prices from Japan's Tokugawa era (1603–1867). The results of cointegration tests indicate that the futures market functioned efficiently during the first sample period (1763–1780),

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*Correspondence author, Faculty of Economics, Kobe University, 2-1, Rokkodai, Nada-Ku, Kobe, 657-8501 Japan; e-mail: hamori@kobe-u.ac.jp

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- *Shigeyuki Hamori is an Associate Professor on the Faculty of Economics at Kobe University in Japan.*
- *Naoko Hamori is a Professor on the Faculty of Information Sciences at the University of Marketing and Distribution Sciences in Japan.*
- *David A. Anderson is an Associate Professor in the Department of Economics at Centre College in Danville, Kentucky.*

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but its efficiency declined during the second sample period (1851–1864).

INTRODUCTION

Futures markets permit market participants to agree on terms for contracts that are to be fulfilled at a later date. This provides security to producers who would suffer from uncertain prices, and allows speculators to bear the burdens and rewards of risk taking. This reallocation of risk serves to open markets that would otherwise be closed, lower prices that might otherwise be prohibitive, and remove uncertainty from those who would be devastated by the downside risk of price variation. The formal inception of futures contracts by the Chicago Board of Trade (CBOT) in 1865 launched the modern era of futures trading.[1] However, the efficiency of today's futures markets and their value to the global economy stem from developments in the rice market of Osaka, Japan during the Tokugawa era (1603–1867). Osaka's Dojima Rice Exchange initiated futures trading in the 1730s. As the modern futures industry expands and innovates to include financial instruments, currencies, and myriad commodities, many of their practices resemble those of the original futures market. The sophistication and ingenuity of Japanese merchants during the Tokugawa era are evident in the development of the Dojima rice market.[2] The purpose of this study is to analyze the efficiency of the Japanese rice market during a defining era for futures markets worldwide, and to assess the relevance of futures trading to Japan's economic development.

Rice itself played a unique role in the Tokugawa era. Land was measured in terms of its output of rice, and feudal lords received annual taxes in the form of rice. The ruling class of samurai warriors lived primarily on revenues received from the taxation of rice. Due to its importance in the economy and its largely homogeneous nature, rice was used as the basic unit of account for financial purposes. It is not too much to say that the economy during the Tokugawa era would not have functioned well if the rice market had not operated smoothly.

Rice transactions were handled in the immediate or "spot" market in the Japanese rice-distribution system of the early Tokugawa era. Rice

[1]CBOT initiated "to arrive" contracts for the future delivery of flour, timothy seed, and hay in 1849, and began "forward" contracts for corn in 1851.

[2]Miyamoto (1988) and Schaede (1989) provide excellent reviews of the development of the Dojima rice market. See Duffie (1989) and Blank, Carter, & Schmiesing (1991) for additional information.

bills were introduced as a means of minimizing the transaction costs of trading large volumes of rice. However, rice bills were not only receipts on rice shipments that lowered the transaction costs. More importantly, these were loans by the merchants to the domains. They were trading IOUs on a futures basis, with rice being backup collateral. Because of relatively good and bad harvests from year to year, farmers needed security against broadly fluctuating prices. The merchants who bought and held large numbers of rice bills also encountered the risks of downturns in the market. Thus, it was important to introduce a means by which to hedge spot trading with futures trading to avoid such risks. Rice bills were suited well for futures trading, and the increased size of rice shipments in the mid-17th century provided market liquidity.

After falling rice prices threatened the livelihoods of warriors and commoners alike, the 8th Shogun, Tokugawa Yoshimune, authorized a futures clearing system in the Dojima district of Osaka in 1730.[3] Osaka was Japan's commodity distribution center, and was referred to as the "kitchen of the country." Influential merchants opened exchange houses in Osaka to render financial services, and rice prices determined at the Dojima rice market became the national standard. The government proactively supported the creation of the market because they wanted traders to gamble in rice in order to drive prices up during a period of deflation. The Dojima rice market constituted the first organized futures exchange in the world. Today's futures markets perpetuate the traditions of their predecessor in Dojima. For instance, then, like now, futures were traded in the market using clearinghouses with a daily membership system, and balances were settled according to the market price of the day.[4] Therefore, it is interesting to examine whether the process of price formation in the Dojima futures market had characteristics similar to those found in current futures markets.

There is controversy regarding the efficiency of the Dojima rice futures market. Miyamoto (1988) demonstrated a high correlation between spot prices and futures prices from 1757 through 1826, and

[3]Tokugawa Yoshimune was called the "Rice shogun." He tried to increase tax revenue by encouraging additional rice-land cultivation, revising the tax system, and enacting sumptuary laws.

[4]Schaede (1989, p. 511) points out the following characteristics of the trading system officially admitted in 1730: (1) one year consisted of three trading periods of a little less than four months each; (2) the number of participants was confined to 1300 licensed rice merchants, i.e., exchange members; (3) all contracts (i.e., rice bills) traded as futures were standardized; (4) contracts were written on a certain brand of standard rice that was designated for each period; (5) all positions had to be cleared on the last day of the period; and (6) the central clearing place, which was an institution made up of a number of individual clearinghouses, assumed contract obligations when a default occurred.

concluded that the Dojima market was efficient. On the other hand, Ito (1993) analyzed the performance of the rice futures market by applying standard regression analysis to data from 1763 to 1780. His primary objectives were twofold. First, he examined whether the futures price at the beginning of a period was an unbiased estimator of the spot price at the end of the period (the unbiased estimator condition). Second, he examined whether the futures price at the end of a period was equal to the spot price at the end of the period (the arbitrage condition). He concluded that the rice market did not perform efficiently between 1763 and 1780.

This study goes beyond Ito's analysis in two ways. First, data from two distinct sample periods was analyzed: 1763–1780 and 1851–1864. During the first period, the strict shogunate system of control and isolation led to political stability. At the same time, advancements in civil engineering increased Japan's tillable acreage and farming output dramatically. The second period is characterized by the substantial political and economic woes of the late nineteenth century (bakumatsu period). This period at the end of the Tokugawa era was marked by chaos, as a revolution replaced the Tokugawa shogunate with new leadership. Political confusion was mirrored by instability in the markets, which at times disrupted the market mechanism. Unlike Ito's analysis, the findings presented here indicate how the performance of the market changed over these differing times and circumstances.

The second contribution is to analyze market efficiency using a unit root test and two variants on a time-series analysis technique called a cointegration test. The unit root test identifies variables that are nonstationary, meaning that they contain a stochastic trend that leads them to wander randomly. It is well known that standard regression procedures should not be applied to nonstationary variables. Although a nonstationary variable tends to wander extensively, some pairs of nonstationary variables move in such a way that they never drift very far apart. This can be the result of disequilibrium forces that keep them together. Such variables are characterized as being "cointegrated." Although they are individually nonstationary, a particular linear combination of them is stationary. Cointegration is an equilibrium relationship that provides a formal framework for testing and estimating long-run (equilibrium) relationships among economic variables that would otherwise be immune to accurate analysis. The application of cointegration tests to futures market data yields new conclusions about the historical efficiency of the Dojima rice market.

DATA

The analysis was performed on data from two sample periods: 1763–1780 and 1851–1864. There are three reasons for the choice of these sample periods. The first is the availability of data. The second is that there was a need to compare the empirical results presented here with Ito's (1993) empirical results. Ito analyzed the efficiency of the market between 1763 and 1780. The first period of this study corresponds to Ito's sample period. The third reason for considering these two distinct periods is to permit analysis of changing market performance over time. The first sample period corresponds to the early stage of the Dojima rice market, whereas the second sample period corresponds to the late stage of the market during the Tokugawa era. It should be meaningful to analyze how the performance of the market changed over time based on these two sample periods.

Data from the earlier period were obtained from Shimamoto (1970); the later data came from Suzuki (1977). Shimamoto (1970) reported the opening and closing futures and spot prices in each dealing period for each trimester (spring, summer, and autumn) in every year from 1763 through 1780.[5] Suzuki (1977) reported daily data on futures and spots for 1851 through 1864. From these collected data, the opening and closing prices were obtained for each dealing period three times per year for the 32 years covered by the two samples.[6]

During both sample periods, futures trades were conducted at the forecasted dealing price of the contract due date three times a year. The dealing periods for spot and futures trading were set as follows:[7]

Spring: the beginning of January through end of April;

Summer: the beginning of May through the beginning of October;

Autumn: mid-October through the end of December.

The final day of each period was the contract date. The rice brokers reported daily the volume and futures price to the clearinghouse, and liquidated the balance three times per month.

[5]Since the opening futures price in the spring of 1767 and the closing futures price in the summer of 1772 are missing, we used data from Tsuruoka (1972) only for these two periods.

[6]In addition to the datasets of Shimamoto (1970) and Suzuki (1977), there is a dataset reported in Tsuruoka (1972). Tsuruoka provides monthly data for the period between 1757 and 1827. Although Tsuruoka's dataset covers a much longer period than either Shimamoto (1970) or Suzuki (1977), precise data on opening and closing futures and spot prices are unobtainable from this source. Furthermore, there are many missing values in Tsuruoka's dataset.

[7]Note that Japan was using the lunar calendar during the Tokugawa era.

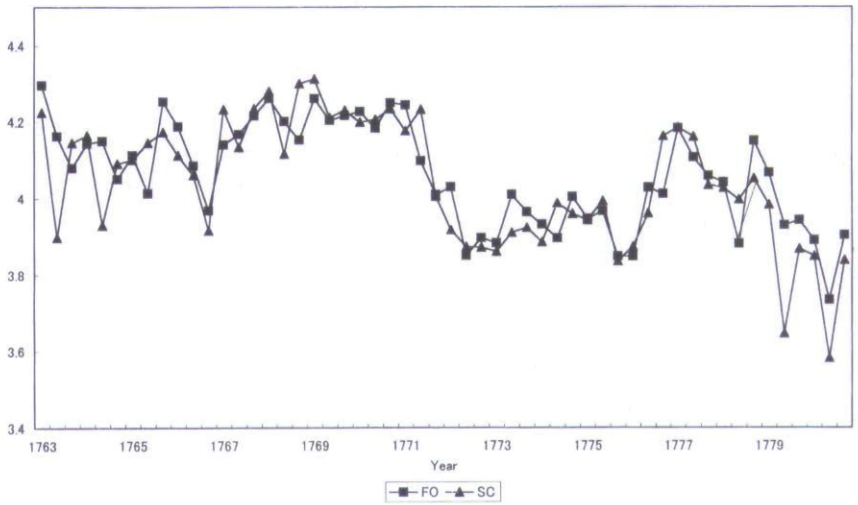

FIGURE 1
FO and *SC* (1763–1780).

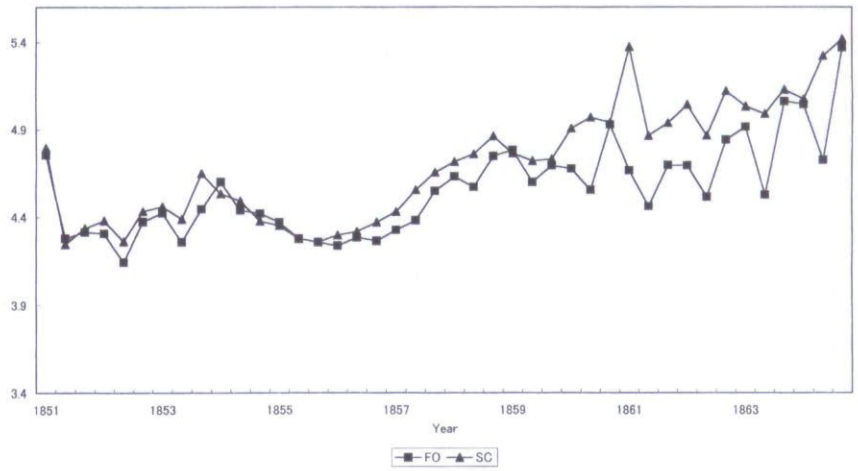

FIGURE 2
FO and *SC* (1851–1864).

Price data are derived from prices at the beginning and end of each dealing period. All variables are measured in logarithms. Figures 1 and 2 show the relationship between the futures price at the beginning of the period (FO_t) and the spot price at the end of the period (SC_t) for each dealing period. Figures 3 and 4 show the relationship between the futures price at the end of the period (FC_t) and the spot price at the end of the period (SC_t) for each dealing period. It is clear from these figures that

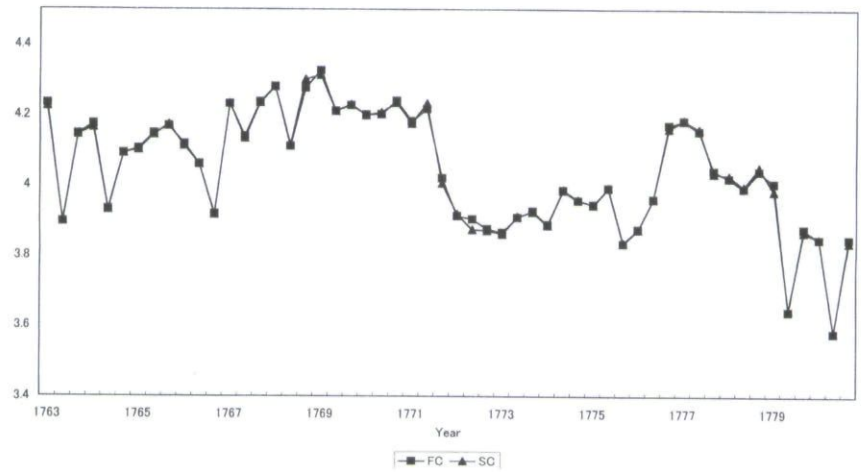

FIGURE 3
FC and *SC* (1763–1780).

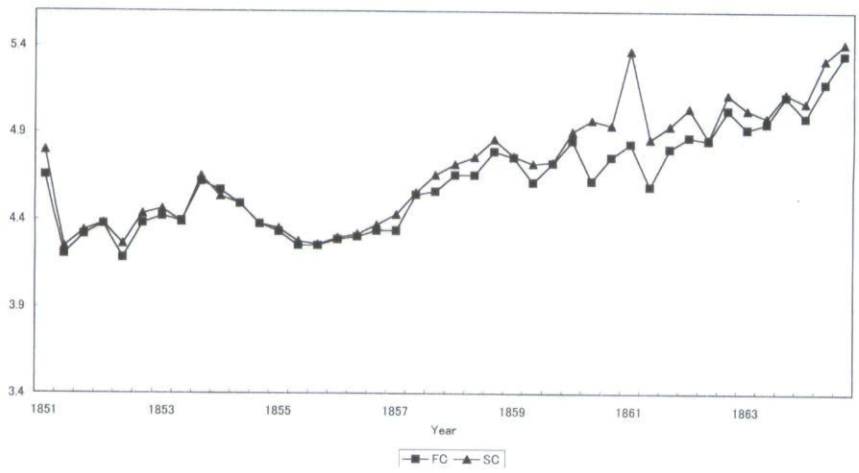

FIGURE 4
FC and *SC* (1851–1864).

the discrepancy between the futures price and the spot price is comparatively small in the first sample period, but increases substantially in the later sample period.

UNIT ROOT TEST

A unit root test is performed to determine whether a variable is stationary. If a variable has a unit root, it is nonstationary and contains a stochastic trend. This determination is relevant because standard

regression analysis should not be applied to a nonstationary variable. The unit root test performed on this data was based on the augmented Dickey–Fuller (ADF) test developed by Dickey and Fuller (1979, 1981). The unit root test statistic is the t value of γ as determined by the following regressions:

$$\Delta Y_t = \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t, \tag{1}$$

$$\Delta Y_t = \alpha + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t, \tag{2}$$

and

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t. \tag{3}$$

In each case, Y_t corresponds to the FO_t, FC_t, and SC_t, Δ is a difference operator ($\Delta Y_t = Y_t - Y_{t-1}$), u_t is the disturbance term with mean zero and finite variance, and $t = 1, 2, \ldots$. In order to verify the robustness of the results, we use the three alternative specifications shown in eq. (1) through (3), and the lag length (p) is chosen to be one or three. The null hypothesis (H_0) and the alternative hypothesis (H_A) are shown as follows:

$$H_0: \gamma = 0,$$
$$H_A: \gamma < 0.$$

In short, the null hypothesis is that "the unit root is included" and the alternative hypothesis is that "the unit root is not included." In Tables I and II, eq. (1) through (3) apply to each of the dependent variables, FO_t, FC_t, and SC_t, with "None" applying to eq. (1); "Constant" applying to eq. (2); and "Constant and Trend" applying to eq. (3).

Table I shows the results of the unit root test on data from the first sample period (1763–1780). Each of the variables involved is found to have a unit root, and therefore to be nonstationary. The robustness of the test results is clear. For each of the variables, formulations, and lag lengths tested, the null hypothesis that a unit root exists cannot be rejected at the 5% significance level. For example, for FO_t, with no deterministic term and a lag length of one, the value of the test statistic is -0.660 and the null hypothesis cannot be rejected at the 5% significance level.

Table II shows the results of the unit root test on data from the second sample period (1851–1864). Again, each of the variables is found to be nonstationary, and the test results are robust across all of the formulations and lag lengths. For instance, for FO_t, with no deterministic term and a lag length of one, the value of the test statistic is 0.845 and the null hypothesis cannot be rejected at the 5% significance level.

TABLE I

Unit Root Test: ADF Test
1763–1780

	Test Statistic					
	Deterministic Term					
	None		*Constant*		*Constant and Trend*	
Variable	$p = 1$	$p = 3$	$p = 1$	$p = 3$	$p = 1$	$p = 3$
FO_t	−0.660	−0.675	−2.121	−1.528	−2.890	−2.418
FC_t	−0.405	−0.644	−1.804	−1.675	−2.865	−2.554
SC_t	−0.411	−0.641	−1.765	−1.680	−2.799	−2.538

Note: FO_t is the futures price at the beginning of period t; SC_t is the spot price at the end of period t; FC_t is the futures price at the end of period t.

None corresponds to the following regression:

$$\Delta Y_t = \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t.$$

Constant corresponds to the following regression:

$$\Delta Y_t = \alpha + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t.$$

Constant and Trend corresponds to the following regression:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t.$$

p is the lag length in the ADF test.

TABLE II

Unit Root Test: ADF Test
1851–1864

	Test Statistic					
	Deterministic Term					
	None		*Constant*		*Constant and Trend*	
Variable	$p = 1$	$p = 3$	$p = 1$	$p = 3$	$p = 1$	$p = 3$
FO_t	0.845	−1.788	−0.821	−0.518	−3.357	−2.010
FC_t	1.731	1.607	0.255	−0.254	−1.817	−2.168
SC_t	1.528	1.562	0.009	−0.341	−2.295	−2.375

Note: FO_t is the futures price at the beginning of period t; SC_t is the spot price at the end of period t; FC_t is the futures price at the end of period t.

None corresponds to the following regression:

$$\Delta Y_t = \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t.$$

Constant corresponds to the following regression:

$$\Delta Y_t = \alpha + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t.$$

Constant and Trend corresponds to the following regression:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + u_t.$$

p is the lag length in the ADF test.

COINTEGRATION TEST

Engle and Granger (1982) developed the cointegration test to examine long-term equilibrium relationships among nonstationary variables. Although nonstationary variables (i.e., those containing a unit root) have a stochastic trend, some pairs or nonstationary variables—those that are cointegrated—are related by a linear combination that is stationary and can be studied.

Two conditions for efficiency in the futures market were examined:

(*i*) *The Unbiased Estimator Condition.* It was determined whether the futures market price at the beginning of a period (FO_t) was an unbiased estimator of the spot market price at the end of the period (SC_t).

(*ii*) *The Arbitrage Condition.* It was determined whether the futures market price at the end of the period (FC_t) corresponded to the spot market price at the end of the period (SC_t).

To examine the first condition, we test whether the cointegrating relation holds between FO_t and SC_t with a cointegration vector $[1, -1]$. That is, it was tested whether $\{z_t\}$ has a unit root by considering the following equation:

$$z_t = FO_t - SC_t. \tag{4}$$

To examine the second condition, it was tested whether the cointegrating relation holds between FC_t and SC_t with a cointegration vector $[1, -1]$. That is, it was tested whether $\{z_t\}$ has a unit root, by considering the following equation:

$$z_t = FC_t - SC_t. \tag{5}$$

The cointegration tests were performed under the following formulation:

$$\Delta z_t = \gamma z_{t-1} + \sum_{i=1}^{p} \delta_i \Delta z_{t-i} + u_t, \tag{6}$$

where u_t is the residual from the regression. The null hypothesis (H_0) and the alternative hypothesis (H_A) are shown as follows:

$$H_0: \gamma = 0,$$
$$H_A: \gamma < 0.$$

The null hypothesis in the tests is that "a cointegrating relation does not exist" and the alternative hypothesis is that "a cointegrating relation exists." The tests were based on the ADF test.

Tables III and IV show the results of the cointegration tests. Table III shows that both the unbiased estimator and arbitrage conditions are accepted at the 5%-significance level for the first sample. Table IV shows that neither the unbiased estimator condition nor the arbitrage condition is accepted at the 5%-significance level for the second sample. These results are robust to the choice of augmentation terms. That is, during the first period, the futures market price at the beginning of the period was an unbiased estimator of the spot market price at the end of the period. In addition, the futures market price at the end of the period closely approximated the spot price at the end of the period—thus disallowing arbitrage. On the other hand, it is clear that neither of these efficiency

TABLE III
Cointegration Test: ADF Test
1763–1780

	Test Statistics	
Variables	$p = 1$	$p = 3$
FO_t and SC_t (Unbiased estimator condition)	−5.124*	−2.317*
FC_t and SC_t (Arbitrage condition)	−5.260*	−3.961*

Note: FO_t is the futures price at the beginning of period t; SC_t is the spot price at the end of period t; FC_t is the futures price at the end of period t.
p is the lag length.
*Indicates that the null hypothesis is rejected at the 5%-significance level.

TABLE IV
Cointegration Test: ADF Test
1851–1864

	Test Statistics	
Variables	$p = 1$	$p = 3$
FO_t and SC_t (Unbiased estimator condition)	−1.476	−0.370
FC_t and SC_t (Arbitrage condition)	−1.662	−1.833

Note: FO_t is the futures price at the beginning of period t; SC_t is the spot price at the end of period t; FC_t is the futures price at the end of period t.
p is the lag length.

conditions was satisfied during the second sample period, and that the market mechanism did not function properly.

A second cointegration test, developed by Johansen (1991) and Johansen and Juselius (1990), was employed to verify these findings. The results of this test, sometimes called the Trace test, or the Johansen test, appear in Tables V and VI. For the first period (Table V), the null hypothesis that there is no cointegration vector is rejected at the 5%-significance level for each variable, while the null hypothesis that there is, at most, one cointegration vector is not rejected. For the second period (Table VI), the null hypothesis that there is no cointegrating relation is not rejected at the 5%-significance level for either variable. Each of these findings is consistent with the corresponding ADF-based cointegration test reported in Table III or IV.

TABLE V
Cointegration Test: Johansen Test
1763–1780

Variables	*Hypothesized Number of Cointegration Vectors*	*Test Statistic*
FO_t and SC_t	None	24.319*
(Unbiased estimator condition)	At most 1	0.290
FC_t and SC_t	None	22.601*
(Arbitrage condition)	At most 1	0.204

Note: FO_t is the futures price at the beginning of period t; SC_t is the spot price at the end of period t; FC_t is the futures price at the end of period t.
*Indicates that the null hypothesis is rejected at the 5%-significance level.

TABLE VI
Cointegration Test: Johansen Test
1851–1864

Variables	*Hypothesized Number of Cointegration Vectors*	*Test Statistic*
FO_t and SC_t	None	11.715
(Unbiased estimator condition)	At most 1	2.669
FC_t and SC_t	None	8.493
(Arbitrage condition)	At most 1	2.978

Note: FO_t is the futures price at the beginning of period t; SC_t is the spot price at the end of period t; FC_t is the futures price at the end of period t.

CONCLUSION

There was remarkable progress in commercial and financial systems in Japan during the Tokugawa era, symbolized by the establishment of futures trading at the Dojima Rice Exchange. This study examines the efficiency of futures trading in the Dojima rice market in that era. We considered two conditions for efficiency: 1) whether the futures price at the beginning of a period was an unbiased estimator of the spot price at the end of that period; and 2) whether the futures market price at the end of a period equaled the spot price at the end of that period. The cointegration tests applied here measure the likelihood of these conditions holding in long-term equilibrium.

Just as the characteristics of the early Dojima rice market are evident in today's markets, the conditions for efficiency also appear to be consistent over time. Based on unit root and cointegration tests, the rice market did perform efficiently amidst the relative calm of the mid-to-late eighteenth century. As in the markets of today's economically and politically secure nations, efficiency was achieved alongside stability. Also, like today, as seen in the less secure economies of eastern Europe and Africa, market efficiency was lost in the face of economic instability and political uncertainty. The apparent failure of the market mechanism during the mid-nineteenth century is likely to have resulted from the political unrest of the revolution, as well as from Osaka's concurrent decline as a center for commerce in Japan. For the Dojima rice market, such disorder hindered the market mechanism and brought identifiable inefficiencies.

The application of cointegration tests, as called for by the characteristics of the data, sheds new light on historical efficiency. The finding of long-run efficiency in the rice futures market over the 1763–1780 period is in contrast to the previous reports by Miyamoto (1988) and Ito (1993). Miyamoto (1988) found that the Dojima rice futures market was efficient from 1757 through 1826, while Ito reported that the market was not efficient between 1763 and 1780. The findings presented here lie in between these two assertions and suggest that the Dojima rice futures market was efficient only in the long run for the period from 1763 to 1780. The finding of long-run efficiency implies that where there exists inefficiency in the short run, error-correction mechanisms can lead the market to long-run equilibrium. The results also showed that even this long-run efficiency disappeared for the period from 1851 to 1864. These revelation that the futures market's efficiency waned during the chaotic bakumatsu period provides empirical support for Miyamoto's (1988) conjectures. The remaining challenge is a more detailed examination of the market mechanism of the Tokugawa era.

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