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The Formation of an Efficient Market in Tokugawa Japan*

Yasuo TAKATSUKI

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Research Institute for Economics and Business Administration

Kobe University

2-1 Rokkodai, Nada, Kobe 657-8501 JAPAN

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Yasuo Takatsuki†

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Abstract

The first modern futures market is said to date back to the Chicago Board of Trade established in 1848. However, an earlier precedent is the Dojima rice market established in 1730 in Osaka. The existing literature makes it clear that the Dojima rice market had well-established trading systems. However, an unanswered fundamental question is whether the market was efficient. In this paper, we first construct a daily price index from the historical document, and then test both the unbiasedness hypothesis and the weak-form efficiency. We show that this type of efficiency existed in this market.

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†Research Institute for Economics and Business Administration, Kobe University, 2-1 Rokkodai, Nada, Kobe 657-8501, Japan. E-mail address: yasuo.takatsuki@gmail.com

I. Introduction

The first modern futures market is said to date back to the Chicago Board of Trade established in 1848. However, an earlier precedent is the Dojima rice market established in 1730 in Osaka, which closed in 1869 because of the collapse of the Tokugawa Shogunate. Many studies of the Dojima rice market (henceforth referred to as the Dojima market) have been published in Japan during the past 70 years. This literature makes it clear that the Dojima market had well-established trading systems. However, an unanswered fundamental question is whether the world's first well-established futures market was efficient. Empirical investigation is yet to establish the efficiency of the Dojima market.

A straightforward way to evaluate the efficiency of the Dojima market trading system would be to test the unbiasedness hypothesis (UBH). By using this method to examine the efficiency of the Dojima market, Ito (1993) and Wakita (2001) reached different conclusions. Ito (1993) concluded that, from 1763 to 1780, the Dojima market failed to satisfy the unbiasedness condition, and thus was not an efficient market. Wakita (2001) applied the same test to monthly data from 1760 to 1864, and concluded that the UBH could not be rejected for at least six months of each of those years; however, he rejected the UBH for all months of the years from 1830 to 1864. These analyses suggest that the Dojima market was not efficient, or was at best only marginally efficient; that is, the first well-established market in the world might not have offered competitive trading opportunities.

However, such a conclusion may be premature because there is some indication that the Dojima market was efficient. The efficiency of the Dojima

market was recognized by traders at that time. A clear example of this is given below.

"Futures trades' virtue lies in the fact that it is, unlike spot trades, robust against sporadic fluctuations of the stock of the goods in Osaka and against other temporal economic shocks. Hence, it naturally allows traders to freely pursue their own benefits, and it would be unaffected by hoarding or dumping. Rather, prices are fixed on the basis of the interaction of among all traders' intention. In particular, the price fixed in this system is much less biased than those fixed in the spot market. The price at the futures market is a mirror of the economic conditions of local regions, from which we can know their general economic circumstances."[1].

This description was presumably written in the late 18th century or later, the period covered by Ito (1993) and Wakita (2001). According to the above description, the futures prices at the Dojima market were regarded as more informative than were the spot prices. In other words, the traders at that time considered the market to be unbiased and thus trusted its futures prices. This recognition is inconsistent with the conclusions of Ito (1993) and Wakita (2001). While Ito (1993) and Wakita (2001) suggest that the Dojima market was at best marginally efficient, the above quote suggests that the Dojima market did have some economic advantages.

The purpose of this paper is to fill this gap between the conclusions reached by current researchers and the historical perceptions held by traders. In this paper, we argue the following: (i) one should construct a daily price index from the original historical document; (ii) one should reexamine the

[1] "Rosei-hiroku", cited by Shimamoto, ed (1970), p10

UBH in the Dojima market; and (iii) one should employ the classic measure of market efficiency proposed by Fama (1970) to test the efficiency of the Dojima market.

The daily price index is needed because the existing monthly and yearly price indices are not suitable for the purpose of this paper, especially in terms of the frequency and length of the period covered by these data. The price index used by Ito (1993) covers the period from 1763 to 1780. As Ito himself recognized, this period represents only a fraction of the history of the Dojima market. Although the monthly price index developed by Tsuruoka (1972) (henceforth referred to as the Tsuruoka Index) that Wakita (2001) used covers a sufficiently long period, it contains many simple, but critical, errors. Moreover, the prices from 1819 to 1827 are not those at the Dojima market but those at another market.

Because the results obtained in previous studies may have been affected by the limitations of these price indices, the conclusions drawn about the efficiency of the Dojima market may be inappropriate. Hence, to reexamine the validity of the UBH in Dojima, one should construct a sufficiently lengthy, reliable, and high-frequency price index. Based on a newly constructed price index, in this paper, we show that Dojima satisfied the unbiasedness conditions from 1798 to 1818.

We also examine the classic measure of market efficiency proposed by Fama (1970), namely"weak-form efficiency".[2] We show that the Dojima market had this type of efficiency.

The structure of this paper is as follows. In Section II, we describe the

[2]A detailed definition is given in Section IV.

institutional aspects of the Dojima market, which serves as background for subsequent discussion. In Section III, we describe the construction of the new daily price index, and reexamine the UBH in the Dojima market. In Section IV, we describe the model used to represent weak-form efficiency, and present an empirical analysis, which is followed by concluding remarks.

II. Institutional Aspects of Dojima

Trades in Dojima

In this subsection, we provide the minimum background necessary for subsequent analysis.[3]

In the Tokugawa era, feudal lords collected rice in kind as tax, and shipped it to the market (mainly Osaka) to finance their local government spending. They stored the rice in their warehouses and sold it at auction, where officially authorized rice brokers bid. Rice brokers who made a successful bid received rice bills which were worth 1500kg per unit of rice stored in the warehouses.[4] In principle, the rice brokers could have submitted their rice bills to the warehouse in exchange for actual rice. However, in practice, they primarily sold the bills on the secondary market, namely the Dojima rice market. Thus, the spot market in Osaka should be regarded as the exchange market for rice bills, not for rice in kind.

[3]See Miyamoto (1988) and Schaede (1989) for further institutional description of the Dojima market.

[4]In the late 17th century, each rice bill corresponded to a particular amount of rice that the broker obtained at auction. Later, this correspondence broke down and rice bills took on the characteristics of securities. See, Shimamoto (1960).

Issuing a rice bill without inventory was officially prohibited by the Shogunate in 1761. However, this did not mean that warehouses actually complied with this restriction, which was acknowledged by the governor in Osaka.[5] That is, while the governor implicitly permitted rice bills to be issued without inventory, he did not allow warehouses to dishonor rice bills. This meant that the claims over rice in kind represented by the rice bills were enforced by the local court in Osaka. [6]

In this spot market, the rice bills had to be delivered in exchange for cash within four days of the transaction. Because of the short delivery time, the spot market was regarded as the market for real demand, not for speculation. While the traders who could operate in the market were limited to officially authorized rice brokers, anybody who paid a fee to the authorized traders could operate in the market. However, more traders joined the futures market, which was useful for speculation.

In the Dojima market, about 30 types of rice bill were issued by feudal lords' warehouses, and the traders' association chose one of these 30 rice bills to constitute standard rice. This standard rice was the underlying asset for the futures trade. As in the spot market, the traders in this market were formally limited to officially authorized members. However, any trader could join the market by paying a small fee to the authorized traders. The fee associated with the futures trades was less than that associated with the spot trades. In addition, less cash was needed in the futures market than in the spot market. These features of the futures market attracted many

[5]The governor, "Osaka-Machi-Bugyo", was in charge of the judiciary, the police, and other administrative services.

[6]For further description, see Takatsuki (2008).

traders, especially speculators.

In principle, the futures market traders had to close their positions by buying back or selling back rice before the maturity date. For example, a trader who made a long position during the trading period had to close his position before the maturity date by selling the amount specified by the contract. Settlement by delivery was permitted before the maturity date, while a constraint designated by the Tokugawa Shogunate was imposed. That is, in the Dojima market, the amount allowed for settlement by delivery was strictly limited to a fixed level of 1000 rice bills for the whole market. Under this constraint, traders dealt in rice bills through the futures market. Usually, net settlements were the main method of settlement.

The trading season

Both the spot and the futures market have three separate trading seasons: January 4–April 27(28), May 7–October 8 (9), and October 17–December 23 (24).[7]. These seasons correspond to the spring, summer, and winter markets, respectively. The markets were closed for about 10 days between any two trading seasons. When a trading season started, the futures market committee was required to reselect the standard rice, which was usually one of the big five lords' varieties.[8]

[7]The dates in parentheses relate to the spot market.

[8]These were from the Kaga, Chikuzen, Chugoku, Higo, and Hiroshima warehouses. Each was deemed to satisfy the conditions of credibility and liquidity.

Trade practices

Trading began at 8 a.m. in the futures market and at 10 a.m. on the spot market. On both markets, trading began with the opening price being presented by the board members of Dojima. In the futures market, the opening price was determined by the closing price of the previous day. The opening price in the spot market was determined by two factors, the closing price from the previous day and the price movements of futures prevailing before the opening of the spot market. This daily lead–lag relationship indicates that the prices at the futures market were regarded as being more informative than those at the spot market.

In both markets, the price was fixed by an open-out-cry system. Traders in the circuit shouted prices by using gestures conveying "ask" or "bid". Because there were no such market makers at the New York Stock Exchange (NYSE), the price was fixed only when the ask price and the bid price matched. Every time a trading deal was established, the clerk of the Dojima market beat a wooden stick and shouted the price. Trades were not written down until the end of the day. At the close of trading, traders submitted their records to the clearing house. The clearing house checked each trader's transaction and canceled out his buying and selling. Then, each trader's remaining position was recorded.

The spot market closed at around noon. The futures market had a one-hour recess at noon and futures trading continued until around 2 p.m. The closing price on the futures market was fixed by using a special method. First, the clerk lit a fire cord. Traders were allowed to trade until the fire went out. The day's closing price was determined as the one prevailing at

the moment the fire went out.

Table 1 summarizes the trading activities at the Dojima market outlined above. The important point is that futures trades at Dojima were designed not for real demand, but for speculation. In addition, the futures market, which opened before the spot market, was expected to enhance the informational efficiency of the spot market.

III. Testing the UBH

The UBH

In this section, the UBH, which has been tested by Ito (1993) and Wakita (2001), is reexamined. Before conducting the empirical analysis, we explain the concept of the UBH and describe previous research. Testing the UBH is a common way of evaluating the efficiency of futures markets. The UBH is based on the assumptions of risk neutrality and rationality. If futures market speculators are risk neutral, and if they use all available information rationally, the current futures price must equal the spot price that is expected to be reached at the maturity date. This relationship is expressed as

$$F_{t-1} = E_{t-1}\left[S_t\right], \tag{1}$$

where S_t is the spot price at time t and F_{t-1} is the value of a futures contract at time $t-1$, which expires at time t. The term E_{t-1} is the expectations operator conditional on information available at time $t-1$. A simple UBH test can be performed by using the following linear regression model:

$$S_t = \alpha + \beta F_{t-1} + u_t. \tag{2}$$

The conditions for unbiasedness are that $\alpha = 0$, $\beta = 1$, and u_t is serially uncorrelated. If these restrictions hold, then futures prices are deemed to be unbiased predictors of future spot prices. In other words, speculators in the market can use all the available information to form rational expectations. The historical details given above imply that this was the case in the Dojima market.

Ito (1993) and Wakita (2001) used this framework to conduct empirical analysis. The model used by Ito (1993) was similar to model (2), as follows:

$$lnSC_t - lnSO_t = \alpha + \beta(lnFO_t - lnFO_t) + e_t, \tag{3}$$

where SO_t and SC_t denote the spot prices at the beginning and the end of trading period t, respectively, and F denotes the futures price. This model can be interpreted as the equivalent of model (2) in terms of logged returns. Having estimated a regression based on this model, Ito (1993) concluded that, from 1763 to 1780, the Dojima market failed to satisfy the unbiasedness conditions.

However, the results described above do not necessarily indicate the inefficiency of the Dojima market because the period covered is relatively short. The price index used by Ito (1993) was obtained from "Hachiboku soubacho (rice price indices)".[9] This price index only covers the period from 1763 to 1780, and contains only the starting and finishing prices of each trading period. Given this limited data availability, Ito (1993) should have estimated

[9]Cited by Shimamoto, ed (1970)

model (3) in order to conduct an appropriate test of the efficiency of the Dojima market.

The framework used by Wakita (2001) has fundamental weaknesses. Wakita (2001) used the following model:

$$\ln S = \alpha + \beta \ln F + \varepsilon_t, \tag{4}$$

where S is the spot price at the beginning of April, September, and December, and F is the futures price. Because the Tsuruoka index used by Wakita (2001) contains only information on prices at the beginning of each month, Wakita (2001) had to use this information rather than information on prices at the maturity date.

Another problem is that Wakita (2001) did not mention the time sequence of the independent variables, that is, the futures prices. Wakita (2001) reported test results for each month, that is, he reported 12 results within each year. It is not clear how he obtained results for April, when the spring market was closed. If he ran the regression between two April prices, then this does not constitute a test of the UBH; rather, it is a test of the arbitrage condition between the spot market and the futures market. If he ran the regression between the spot prices in September and the futures prices in April, then neither does this constitute a test of the UBH. This is because the "standard price" in the spring market and the price in the summer market are not the same, and "roll over" across the trading season was strictly prohibited in the Dojima market. Therefore, the results obtained by Wakita (2001) cannot be considered to represent an appropriate test of the efficiency of the Dojima

market. [10]

From the above discussion, the question of whether the Dojima market satisfied the UBH remains unanswered. Thus, reexamination based on a newly constructed price index is called for.

The price index

To overcome the problems associated with the price indices used in existing studies, we construct a more reliable and high-frequency price index from the original historical documents. Our new price index is obtained from "Yorozu souba nikki (daily memorandum of commodity price indices)".[11] This memorandum was written by the contemporary rice merchant who dealt in rice and fertilizer. This merchant joined the Dojima futures market for speculation, and for this reason he recorded the commodity price indices in his memorandum. From this memorandum, we can construct daily price indices in both the futures and spot markets for the period from 1798 to 1856.

In addition, there is another price index constructed by Suzuki (1935). This index (henceforth referred to as the Suzuki index) covers the period from 1834 to 1864, and contains both futures prices and spot prices.[12] The

[10] Another problem with the study of Wakita (2001) is that he did not use the spot price in October. As explained in Section II, the summer market was closed in October, not in September. Yet another problem is that he reported results for the period from 1830 to 1864 but, to the best of my knowledge, no price index is available for the period from 1830 to 1833.

[11] The Tsuruoka index was also constructed from this memorandum. However, in constructing this new daily price index, we found that the Tsuruoka index contains errors.

[12] Despite its apparent appeal, the Suzuki index requires careful treatment. This index

price index formed from these two indices enables one to cover the period from 1798 to 1864.[13]

Reexamination of the UBH

The model used in this paper can be expressed as follows:

$$lnSC_t - lnSC_{t-1} = \alpha + \beta(lnFO_t - lnFO_{t-1}) + u_t, \tag{5}$$

where SC_t is the spot price at the maturity date of trading season t and FO denotes the futures price at the beginning of the trading season. The condition for unbiasedness is that $\alpha = 0$, $\beta = 1$, and u_t is serially uncorrelated.

The test results are summarized in Table 2. As Table 2 indicates, the UBH in the whole period is rejected at the 1 % significance level. However, for the period from 1798 to 1835, the UBH is not rejected at the 1 % significance level. That is, the speculators in the Dojima market used all the available information and formed rational expectations. This period coincides with the period when the historical description given above was written. Thus,

lacks closing prices for the futures market from 1857 to 1864. However, the opening price of the futures market was determined by the Dojima committee based on the previous day's closing price. There is no significant difference between the closing price at time $t-1$ and the opening price at time t; That is, the null hypothesis that the closing price at time $t-1$ and the opening price at time t are the same in variance and mean was accepted at the 1% significance level. Hence, we substitute the closing price at time $t-1$ for the opening price at time t.

[13]The prices in the period form 1836 to 1839, and in 1849 was not recorded in both Suzuki index and "Yorozu souba nikki". In addition, the prices in the period from 1819 to 1833 can not be observed because the documents' state of preservation is very poor.

our results support the perceptions held by traders at that time that futures prices were unbiased estimators of future spot prices. According to Ito (1993), for the period from 1763 to 1780, the UBH was rejected. Taking this result into account, it can be said that the efficiency of the Dojima market, in terms of the rational expectations, was achieved during the period from 1780 to 1835. Table 2 also indicates that the UBH was rejected at the 1 % significance level for the period from 1840 to 1864 (the end of the Tokugawa period). Hence, at that stage, rational expectations formation in the Dojima market was impaired for some reason.

These results indicate that the Dojima market, in terms of the rational expectations, achieved efficiency in the middle of the Tokugawa period. Because rational expectations are formed by traders who incorporate all the available information into their prices, it can be concluded that the Dojima market, in this period, reflected all available information. According to Fama (1970), "A market in which prices always 'fully reflect' available information is called 'efficient'." Thus, in this period, the Dojima market, exhibited informational efficiency.

What about other periods? Although informational efficiency is a significant necessary condition for the formation of rational expectations, rejection of the UBH for the end of the Tokugawa period does not necessarily mean that the Dojima market, in this period, did not have informational efficiency. Ito (1993) and Wakita (2001) did not investigate this, precisely because of the lack of a high-frequency price index. In the next section, we examine the informational efficiency of the Dojima market using the newly constructed daily price index.

IV. Weak-form Efficiency

Market efficiency

The concept of market efficiency with respect not to resource allocation, but to information sets, was first defined in a classical study by Fama (1970). Checking this informational efficiency is equivalent to checking how much, how fast, and how accurately available information is incorporated into securities prices. Financial economists often classify this informational efficiency into three categories based on what is meant as "available information"; that is, there are weak, semistrong, and strong forms of informational efficiency.

In this paper, we focus on weak-form efficiency, which is the most objective of these criteria. Weak-form efficiency exists if securities prices fully reflect all the information incorporated in past prices and returns. If markets have weak-form efficiency, then traders cannot earn excess profits from trading rules based on past prices or returns. Therefore, investment returns are not predictable.

Weak-form efficiency is the most objective criterion because if this does not hold, then neither semistrong nor strong-form efficiency can be satisfied. Moreover, information on past prices are assumed to be the most accessible information available to traders in the Dojima market.[14] For these reasons, we start with this most basic, but most significant, criterion.

A straightforward way to check for weak-form efficiency is to estimate autocorrelations of the price sequences. If the price sequences do not exhibit

[14]Recall that the "Yorozu souba nikki (daily memorandum of commodity price indices) was written by a contemporary rice merchant.

autocorrelation, we can conclude that traders could not exploit historical information on price behavior in order to obtain excess returns. Fortunately, we can take advantage of the daily price index both in the futures market and in the spot market.

The test statistics

The most widely used statistic for testing for market weak-form efficiency is the Q-statistic proposed by Box and Pierce (1970). This statistic is given by

$$Q_m \equiv T \sum_{k=i}^{m} \rho^2(k), \tag{6}$$

where $\rho(k)$ is the kth-order autocorrelation coefficient, and T is the sample size. Under the null hypothesis, $\rho(k) = 0$, with $Q_m = T \hat{\sum}_{k=i}^{m} \rho^2(k)$ being asymptotically distributed as χ^2_m.

By summing the squared autocorrelations, the Box–Pierce Q-statistic is designed to detect departures from zero autocorrelations in either direction and at all lags.

Ljung and Box (1978) provide the following finite-sample correction, which yields a better fit to the χ^2_m for small sample sizes:

$$Q'_m \equiv T(T+2) \sum_{k=i}^{m} \frac{\rho^2(k)}{T-k}. \tag{7}$$

We calculate the Ljung and Box Q-statistics for up to 5 lags, as follows:

$$Q'_5 \equiv T(T+2) \sum_{k=i}^{5} \frac{\rho^2(k)}{T-k}. \tag{8}$$

The null hypothesis is given as $H_0 : \rho(k) = 0, \forall k \leq 5$.

Results

The test results are shown in Table 3.[15] As Table 3 indicates, for the spot and futures markets, respectively, the null hypotheses cannot be rejected in about 80% and 70% of the periods. Based on these results, we can conclude that both markets succeeded in accurately reflecting past price movements. In addition, as Table 4 indicates, there is no evidence of any pattern.[16] That is, weak-form efficiency is detected uniformly, and even at the end of the Tokugawa period, the Dojima market was thought to have this type of efficiency. Table 5 indicates that weak-form efficiency was detected as more prevalent in the winter market, when newly harvested rice came on the market.[17] This suggests that the liquidity level of supply, which was lower in the spring and summer markets and higher in the winter market, may have affected trading activity in the market.

Concluding Remarks

In this paper, we have shown that the Dojima market had a well-established market mechanism, and more importantly, exhibited rational expectations formation and weak-form efficiency. Thus, unlike previous researchers, we have obtained evidence of the efficiency of the Dojima market, which was

[15]The numbers attached to the years, namely 1834-1, 1834-2 and 1834-3 indicates spring, summer, winter market respectively. The column "Efficiency" is "Y" when the null hypotheses are not rejected in 5% significance level, and is "N" otherwise.

[16]The percentages were calculated by dividing the number of the periods in which the null hypotheses are not rejected, by the number of the period in total.

[17]The percentages were calculated in the same manner as Table 4.

recognized by contemporary traders.

Finding evidence of this type of efficiency in the Dojima market is surprising because this does not necessarily hold even in contemporary modern financial markets equipped with information and communications technology.[18] In this paper, because we only investigated weak-form efficiency, finding evidence of semistrong or strong-form efficiency remains a challenging task for future inquiry.

[18]The unbiasedness hypothesis has been rejected in many empirical studies of various commodity futures markets; see, for example, Fama (1984), Baillie and Myers (1991), Bessler and Covey (1991), and Chowdhury (1991). Neither does weak-form efficiency necessarily hold in contemporary financial markets. Lo and MacKinlay (1988) found that weekly returns on portfolios of NYSE stocks grouped according to size show significant positive autocorrelation, and that the autocorrelation is stronger for portfolios of small stocks. See Fama (1991) for an elaboration of these issues.

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Historical document

"Yorozu Souba Nikki (daily memorandum of commodity price indices)," held by Kokubungaku Kenkyushiryokan Rekishishiryo Etsuranjimushitsu (Office of Archives Services in the National Institute of Japanese Literature), Tokyo, Japan.

Table 1: The trading rules in the Dojima market

	Futures Market	Spot Market
Goods in trades	The standard rice (index)	The rice bills
Trading priods	January 4-April 27 May 7-October 8 October 17-December 23	January 4-April 28 May 7-October 9 October 17-December 24
Trading time	From 8 a.m. to 2 p.m.	From 10 a.m. to the noon
Trading system	Open-Out-Cry	Open-Out-Cry
Settlement	Net settlement	Delivery within 4 days

Table 2: Results of the test of the UBH

Period	1798-1864	1798-1818	1834-1864
α	-13.430	11.189	-3.569
β	1.266	0.803	1.188
R-squared	0.783	0.521	0.719
F-value	22.994	2.848	17.844
P-value	0.000	0.066	0.000

Table 3: Results of the Q-tests

periods	Futures	Spot	periods	Futures	Spot	periods	Futures	Spot	periods	Futures	Spot
1798-1	Y	Y	1810-1	Y	Y	1841-1	N	Y	1854-1	Y	Y
1798-2	Y	N	1810-2	Y	Y	1841-2	N	Y	1854-2	Y	Y
1798-3	Y	Y	1810-3	Y	Y	1841-3	N	Y	1854-3	Y	N
1799-1	Y	Y	1811-1	Y	N	1842-1	N	Y	1855-1	Y	Y
1799-2	N	Y	1811-2	Y	Y	1842-2	N	Y	1855-2	N	Y
1799-3	Y	Y	1811-3	Y	Y	1842-3	Y	Y	1855-3	Y	Y
1800-1	N	N	1812-1	Y	Y	1843-1	N	N	1856-1	Y	Y
1800-2	N	Y	1812-2	Y	Y	1843-2	N	Y	1856-2	Y	Y
1800-3	Y	Y	1812-3	Y	Y	1843-3	Y	N	1856-3	N	Y
1801-1	Y	Y	1813-1	Y	Y	1844-1	N	Y	1857-1	Y	Y
1801-2	Y	Y	1813-2	N	Y	1844-2	Y	N	1857-2	Y	Y
1801-3	Y	Y	1813-3	N	Y	1844-3	Y	Y	1857-3	Y	Y
1802-1	Y	Y	1814-1	Y	Y	1845-1	Y	Y	1858-1	Y	Y
1802-2	N	Y	1814-2	N	Y	1845-2	Y	Y	1858-2	Y	Y
1802-3	Y	Y	1814-3	Y	N	1845-3	Y	Y	1858-3	Y	Y
1803-1	Y	Y	1815-1	Y	N	1846-1	Y	Y	1859-1	Y	Y
1803-2	N	Y	1815-2	Y	Y	1846-2	Y	N	1859-2	Y	Y
1803-3	Y	Y	1815-3	Y	Y	1846-3	Y	Y	1859-3	Y	Y
1804-1	Y	Y	1816-1	N	Y	1847-1	Y	Y	1860-1	Y	Y
1804-2	N	N	1816-2	Y	Y	1847-2	N	N	1860-2	Y	Y
1804-3	Y	Y	1816-3	Y	Y	1847-3	Y	Y	1860-3	N	Y
1805-1	Y	Y	1817-1	N	N	1848-1	N	N	1861-1	Y	N
1805-2	Y	Y	1817-2	N	N	1848-2	Y	N	1861-2	Y	Y
1805-3	N	Y	1817-3	Y	N	1848-3	Y	N	1861-3	Y	Y
1806-1	Y	Y	1818-1	Y	Y	1850-1	N	Y	1862-1	N	Y
1806-2	Y	Y	1818-2	Y	Y	1850-2	N	Y	1862-2	N	Y
1806-3	Y	N	1818-3	Y	Y	1850-3	N	Y	1862-3	Y	Y
1807-1	Y	Y	1834-1	Y	N	1851-1	Y	Y	1863-1	N	N
1807-2	N	Y	1834-2	Y	Y	1851-2	N	Y	1863-2	N	Y
1807-3	Y	Y	1834-3	Y	Y	1851-3	Y	Y	1863-3	Y	Y
1808-1	Y	Y	1835-1	Y	Y	1852-1	Y	Y	1864-1	N	Y
1808-2	Y	Y	1835-2	Y	Y	1852-2	Y	N	1864-2	Y	N
1808-3	N	Y	1835-3	Y	Y	1852-3	Y	N	1864-3	Y	Y
1809-1	Y	Y	1840-1	N	Y	1853-1	N	N			
1809-2	Y	Y	1840-2	Y	N	1853-2	Y	Y			
1809-3	N	Y	1840-3	Y	Y	1853-3	Y	Y			

Table 4: Patterns of the Q-tests results in each period

periods	Futures	Spot
1798-1864	71.6%	80.9%
1798-1818	74.6%	84.1%
1834-1864	69.2%	78.2%

Table 5: Seasonal patterns of the Q-tests results

Spring market			Summer market			Winter market		
periods	Futures	Spot	periods	Futures	Spot	periods	Futures	Spot
1798-1864	70.2%	78.7%	1798-1864	61.7%	78.7%	1798-1864	83.0%	85.1%
1798-1818	85.7%	81.0%	1798-1818	57.1%	85.7%	1798-1818	81.0%	85.7%
1834-1864	57.7%	76.9%	1834-1864	65.4%	73.1%	1834-1864	84.6%	84.6%