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Efficiency tests of agricultural commodity futures markets in China

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The efficiency of the Chinese wheat and soybean futures markets is studied. Formal statistical tests were conducted based on Johansen's cointegration approach for three different cash markets and six different futures forecasting horizons ranging from 1 week to 4 months. The results suggest a long-term equilibrium relationship between the futures price and cash price for soybeans and weak short-term efficiency in the soybean futures market. The futures market for wheat is inefficient, which may be caused by over-speculation and government intervention.

Key words: cointegration, futures market, price, soybean, wheat.

1. Introduction

China began significant economic reforms in 1978, transforming its centrally planned economy into a largely market-oriented one. In December 1990, the first agricultural wholesale market, the Zhengzhou Grain Wholesale Market (ZGWM), was established with the assistance of the Chicago Board of Trade (CBOT). Three years of successful forward contracting was followed by the establishment of the China Zhengzhou Commodity Exchange (CZCE), which bases its operation on the ZGWM.

The CZCE specialises in the trading of agricultural commodity futures contracts. Mung beans were the first futures commodity traded in the CZCE and this trade flourished initially. Because mung beans are not a major agricultural product, this active trading was almost exclusively a result of speculation. Almost 300 million tons of mung beans were traded during a 1-year period between August 1998 and August 1999, yet the total actual production was less than 1 million tons per year. Mung bean futures have now been largely phased out of the market by a large increase in the required margin account, now at 20 per cent. However, wheat futures trading in CZCE has shown significant growth. Over 14 million contracts were traded in 2001, compared to less than 200 000 in 1996.

Currently, there are three futures exchanges in China: the CZCE, the Dalian Commodity Exchange (DCE) and the Shanghai Futures Exchange (SFE). The SFE specialises in trading metals, while both the CZCE and the DCE trade in agricultural commodity futures, primarily wheat in the CZCE and soybean in the DCE. The DCE

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is now the second largest soybean futures market in the world after the CBOT, with a trading volume nearly four times larger than the Tokyo Commodity Exchange (Food China 2001). Contract specifications and trading rules for the wheat and soybean futures markets are explained in the Appendix.

The aim of this study is to test the efficiency of these new futures markets for agricultural commodities in China. An efficient commodity futures market can provide effective signals for the spot market price and eliminate the possibility that profit can be guaranteed as part of the trading process. This futures price reflects the equilibrium value for suppliers and buyers in the market.

The study of efficiency in agricultural commodity futures markets is important to the government as well as producers and purchasers in China. For the government, an efficient market is a better alternative than market intervention through policies. For processors and marketers, it provides a reliable forecast of spot prices in the future allowing them to effectively manage their market risks. It is also in the interests of international market participants from countries like Canada, the USA, Australia and the European Union, who are the major grain exporters to China (USDA FAS 2002). This study can provide them with some knowledge of the conditions in Chinese agricultural commodity futures and cash markets.

Although China's successful economic reform has attracted international attention from economists (Carter and Rozelle 2001; Martin 2001), studies on futures markets in China, especially quantitative ones, are rare. In this study, we use a quantitative approach to test the efficiency of agricultural futures markets. Specifically, we examine: (i) the long-run equilibrium relationship between the futures price and the cash price; (ii) the efficiency of the futures market as a predictor of the cash market; and (iii) the relative performance of the futures prices in forecasting cash prices over different forecasting horizons. We focus on the two major agricultural commodities traded in China: wheat in the CZCE and soybean in the DCE. The remainder of the paper is organised as follows: the next section is a summary of theoretical and empirical studies related to market efficiency tests; the third section contains details of the statistical tests for the efficiency of futures markets; empirical results are presented after a brief explanation of the data; and the last section presents the conclusions.

2. Literature review

There are few studies on futures markets in China and most of the existing studies emphasise legislative or other development issues (Tao and Lei 1998; Fan *et al.* 1999; Zhu and Zhu 2000). Yao (1998) provides a detailed structural analysis of China's commodity futures markets, their historical development and the government's legislative and regulatory program in the first half of the 1990s.

Williams *et al.* (1998) studied mung bean trading in the CZCE and found that conditions for arbitrage existed, a sign of inefficiency. Durham and Si (1999) examined the relationship between DCE and CBOT soybean futures prices and concluded that the soybean futures price in DCE was influenced by the CBOT price. Du and Wang (2004) investigated the relationship between CZCE and CBOT wheat prices and found that the two price series showed similarities.

There are numerous studies, both theoretical and empirical, that analyse the efficiency of futures markets in developed countries such as the USA. Fama (1970) provided a thorough summary of the early works on market efficiency testing. Although most efficiency studies are for financial securities, agricultural commodity analyses can also be found. A simple linear regression model was used by Bigman *et al.* (1983) for wheat, corn and soybean trading at the CBOT. In further studies, Maberly (1985), Elam and Dixon (1988), and Shen and Wang (1990) showed that this model was invalid for non-stationary price series.

The development of the cointegration theory by Engle and Granger (1987) provided a new technique for testing market efficiency when prices are non-stationary. Aulton *et al.* (1997) re-investigated the efficiency of the UK agricultural commodity futures markets using the cointegration method. A limitation of this approach is that no strong inferences can be drawn for the parameters (Lai and Lai 1991).

Johansen (1988, 1991) and Johansen and Juselius (1990) derived statistical procedures for testing cointegration using the maximum-likelihood method. These procedures are based on a vector autoregression (VAR) model that allows for possible interactions in the determination of spot prices and futures prices. Lai and Lai (1991) recommended Johansen's approach for testing market efficiency. Subsequently, Johansen's approach has been applied widely. Fortenbery and Zapata (1993) evaluated the relationship of two North Carolina corn and soybean markets with respect to the CBOT. They could not reject cointegration or efficiency. Kellard *et al.* (1999) examined the efficiency of several widely traded commodities in different markets, including soybean on the CBOT and live hogs and live cattle on the Chicago Mercantile Exchange. They also found a long-run equilibrium relationship but a short-run inefficiency for most of the markets studied. McKenzie and Holt (2002) tested the efficiencies of the USA futures markets for cattle, hogs, corn, soybean meal and broilers. Their results indicated that futures markets for all the commodities except broilers were both efficient and unbiased in the long run.

3. Methods

In the present paper, the Johansen approach is used to test the efficiency of Chinese agricultural commodity futures. A non-stationary time series is said to be integrated in order 1, often denoted by I(1), if the series is stationary after first-order differencing. An $(n \times 1)$ vector time series $\boldsymbol{Y}_t$ is said to be cointegrated if each of the n series taken individually is I(1), while some linear combination of the series $\boldsymbol{AY}_t$ is stationary for some non-zero vector $\boldsymbol{A}$ (Hamilton 1994).

The theory of cointegration relates to the study of the efficiency of a futures market in the following way. Let S_t be the cash price at time t and F_{t-i} be the futures price i periods before the contract matures at time t. If the futures price can provide a predictive signal for the cash price i periods ahead, then some linear combination of S_t and F_{t-i} is expected to be stationary. That is, there exists a and b such that,

$$z_t = S_t - a - bF_{t-i}, \tag{1}$$

is stationary with mean zero. If both S_t and F_{t-i} are I(1), a condition that usually holds for prices, the vector (S_t, F_{t-i}) is then cointegrated. This cointegration between S_t and

F_{t-i} is a necessary condition for market efficiency (Lai and Lai 1991). This is because cointegration ensures that there exists a long-run equilibrium relationship between the two series as expressed in Equation (1). If S_t and F_{t-i} are not cointegrated, they will drift apart without bound, so that the futures price provides little information about cash price movements.

Because the relationship between the cash price and the current futures price (which is for a deferred delivery date) is affected by a market carrying cost, this carrying cost should be included in Equation (1), through either z_t or a. If the carrying cost is also random and non-stationary, then z_t might be non-stationary even if the futures market is an efficient predictor for the cash market. One non-stationary component of the carrying cost, the interest rate, was included explicitly in the equation by Zapata and Fortenbery (1996). Other components of the carrying cost such as risk premiums, convenience yields and physical storage costs are not observable and are generally not included in the equation. Here we exclude all carrying cost components from Equation (1), assuming that they are stationary. This is a reasonable assumption for China in a period when the financial market was not developed and the interest rate was tightly controlled without much variation.

In addition to cointegration, market efficiency also requires that the futures price provides an unbiased forecast of the cash price (i.e., $a = 0$ and $b = 1$). Therefore, market efficiency should be tested in two steps: (i), determine whether the two price series S_t and F_{t-i} are cointegrated; and (ii), if they are, test the restriction on the parameters $a = 0$ and $b = 1$. The second step may consist of multiple tests: $a = 0$ and $b = 1$ jointly, or each individually. The constraint $b = 1$ is the most important indicator of market efficiency because a is non-zero under the existence of a risk premium or transportation costs even when the market is efficient. The cointegration relationship and the parameter restrictions can be tested as explained below.

3.1 Cointegration tests

Before testing for cointegration, each individual price series should be examined to determine whether they are I(1). Augmented Dickey–Fuller (ADF) and the Phillips–Perron unit root tests are the common methods (Chowdhury 1991; Lai and Lai 1991; McKenzie and Holt 2002) and are used here. If both the futures price and cash price are I(1), Johansen's cointegration tests can then be conducted through a kth-order vector error correction (VEC) model of the form:

$$\Delta \boldsymbol{Y}_t = \boldsymbol{\Phi} \boldsymbol{D}_t + \boldsymbol{\Pi} \boldsymbol{Y}_{t-1} + \sum_{i=1}^{k-1} \boldsymbol{\Gamma}_i \Delta \boldsymbol{Y}_{t-i} + \boldsymbol{\varepsilon}_t, \tag{2}$$

where $\boldsymbol{Y}_t$ is an $(\boldsymbol{n} \times 1)$ vector to be tested for cointegration; $\Delta \boldsymbol{Y}_t = \boldsymbol{Y_t} - \boldsymbol{Y_{t-1}}$; $\boldsymbol{D}_t$ is a deterministic term consisting of a vector of seasonal dummy variables; $\boldsymbol{\Phi}$, $\boldsymbol{\Pi}$ and $\boldsymbol{\Gamma}$ are coefficient matrices; and k is chosen such that $\boldsymbol{\varepsilon}_t$ is a multivariate normal white noise process with mean zero and finite covariance matrix.

The existence of a cointegrating relationship can be determined by examining the rank of the coefficient matrix $\boldsymbol{\Pi}$. Specifically, the number of cointegrating vectors equals the rank of $\mathbf{\Pi}$ (Johansen and Juselius 1990). Johansen (1988) suggested two test statistics to test the null hypothesis that there are at most r cointegrating vectors. The null hypothesis can be equivalently stated as the rank of $\mathbf{\Pi}$ is at most r, for $r = 0, 1, \ldots, n-1$. The two test statistics are based on the trace and maximum eigenvalues of $\mathbf{\Pi}$, respectively:

$$\lambda_{\text{trace}} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i), \tag{3}$$

$$\lambda_{\max} = -T \ln(1 - \hat{\lambda}_{r+1}), \tag{4}$$

where T is the sample size; and $\hat{\lambda}_1, \ldots, \hat{\lambda}_r$ are the r largest squared canonical correlations between the residuals obtained by regressing $\Delta \boldsymbol{Y}_t$ and $\boldsymbol{Y}_{t-1}$ on $\Delta \boldsymbol{Y}_{t-1}, \Delta \boldsymbol{Y}_{t-2}, \ldots, \Delta \boldsymbol{Y}_{t-k-1}$ and the seasonal dummy variables, respectively.

In our test for futures and cash market cointegration, $\boldsymbol{Y}_t = (S_t, F_{t-i})'$, $n = 2$, and the null hypothesis should be tested for $r = 0$ and $r = 1$. If $r = 0$ cannot be rejected, we will conclude that there is no cointegrating vector and, therefore, no cointegration. However, if $r = 0$ is rejected and $r = 1$ cannot be rejected, we will conclude that there is a cointegrating relationship.

A vector of constants is included in the error correction model to allow a non-zero difference between the cash and futures prices in their long-run relationship and the constants are under the same restrictions as described by Osterwald-Lenum (1992) under case 1*. The restrictions are imposed by introducing a 1 in the vector variable $\boldsymbol{Y}^*$, where $\boldsymbol{Y}_t^* = (S_t, F_{t-i}, 1)'$. The details of this method can be found in Lai and Lai (1991) and the critical values are provided by Osterwald-Lenum (1992).

3.2 Weak exogeneity test

Even if a long-run equilibrium relationship between cash and futures prices is established, the two prices may still move away from the relationship from time to time due to transitory shocks. A weak exogeneity test can be used to test whether the equilibrium relationship can be restored quickly. If a price does not react to a shock in the long-run relationship, it is said to be 'weakly exogenous'. If a cointegrating relationship exists then the coefficient matrix $\mathbf{\Pi}$ in Equation (2) can be decomposed as $\Pi = \boldsymbol{\alpha\beta}'$, where $\boldsymbol{\beta}$ is the cointegrating vector and $\boldsymbol{\alpha}$ is a loading vector that measures the average speed of convergence towards the long-run equilibrium. The larger the value of $\boldsymbol{\alpha}$, the faster the two price series converge to equilibrium (Haigh 2000). If a price is weakly exogenous then the corresponding element of $\boldsymbol{\alpha}$ will be zero. A likelihood-ratio statistic can be used to test the null hypothesis that the ith element of $\boldsymbol{\alpha}$ is zero, $\alpha_i = 0$, for $i = 1, \ldots, n$. The statistic has a chi-square distribution with one degree of freedom under the null hypothesis.

3.3 Restrictions on cointegrating vectors

If the futures price and the cash market price are cointegrated, we can then test restrictions on the parameters in Equation (1). Cointegration implies that there exists a cointegrating vector $\boldsymbol{\beta}$ such that $z_t = \beta' \boldsymbol{Y}_t^*$ is stationary – in the present context

$\beta' = (1, -b, -a)$. The market efficiency hypotheses can therefore be tested by imposing restrictions on the cointegrating vector $\boldsymbol{\beta}$. For example, the hypothesis of $a = 0$ and $b = 1$ is expressed as $\beta' = (1, -1, 0)$. The standard likelihood-ratio test can be used and the test statistic can also be expressed using canonical correlations (Johansen and Juselius 1990) as:

$$L_r = T\sum_{i=1}^{r}\ln\left(\frac{1-\lambda_i^*}{1-\hat{\lambda}_i}\right), \tag{5}$$

where $\hat{\lambda}_1^*, \ldots, \hat{\lambda}_r^*$ are the r largest squared canonical correlations under the null hypothesis (i.e., the restricted model) and $\hat{\lambda}_1, \ldots, \hat{\lambda}_r$ are the r largest squared canonical correlations under the full or unrestricted model. The test statistic follows an asymptotic chi-square distribution with the degrees of freedom equalling the number of restrictions imposed.

Unfortunately, the likelihood-ratio test in Equation (5) is an asymptotic test, and when the sample size is small it often leads to incorrect rejection of the null hypothesis. Psaradakis (1994) suggested the following simple correction to the test statistic that can improve the performance of the test in small samples:

$$\bar{L}_r = \frac{T - m/n}{T} L_r, \tag{6}$$

where m is the number of parameters estimated in Equation (2). This modification is adopted in the present paper because our sample size is small.

4. Data

Two cash markets, the ZGWM and the Tianjin Grain Wholesale Market (TGWM) for both wheat and soybean, are chosen to test the efficiency of the CZCE and DCE futures markets.[1] The ZGWM is located in Central China, which is the major wheat production area. The TGWM, established in 1994, is another major agricultural wholesale market in China. Figures 1 and 2 show the 2002 production distribution in China for wheat and soybeans. Another cash price, the national average price, is also included in the tests. The national average price is calculated based on prices from several major markets across the country. Although it does not relate to a specific market, the national average price is often used as a cash market price index, especially in some macroeconomic and international trade studies.

Weekly futures price data on wheat and soybean over the period January 1998 to March 2002 are provided by the CZCE and the DCE. Cash prices are obtained from the CnGrain online database (China Grain Reserves Corporation 2000). There are six contracts each year for both commodities: January, March, May, July, September

[1] Time series of price data from other major wholesale markets in China, such as Fuzhou and Jiangxi, are not available for a sufficiently long period of time. These markets are also less important for the two commodities because they are far away from the production areas and the trading volumes are low.

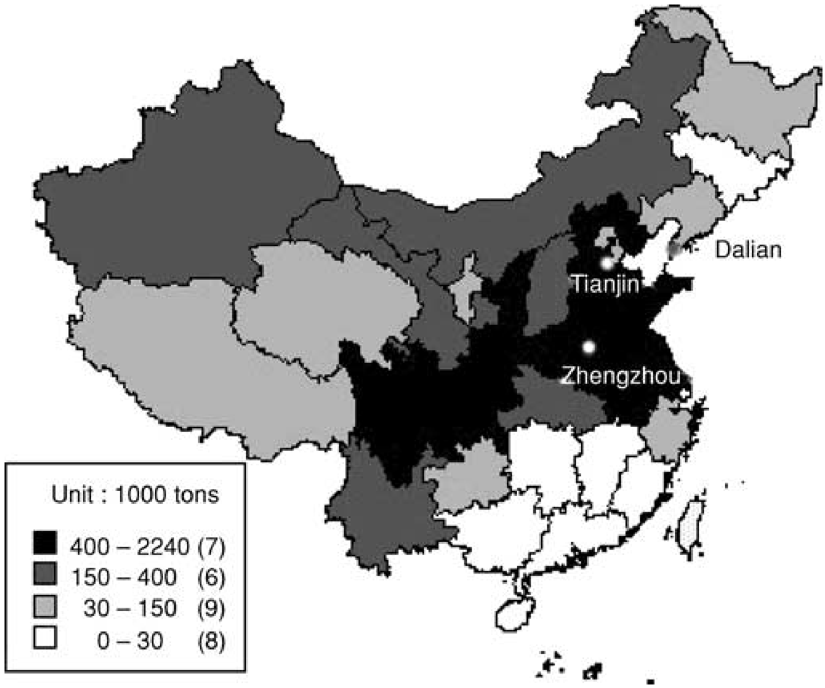

Figure 1 China's wheat production map (2000) and selected markets data. Source: China Bureau of Statistics (2002).

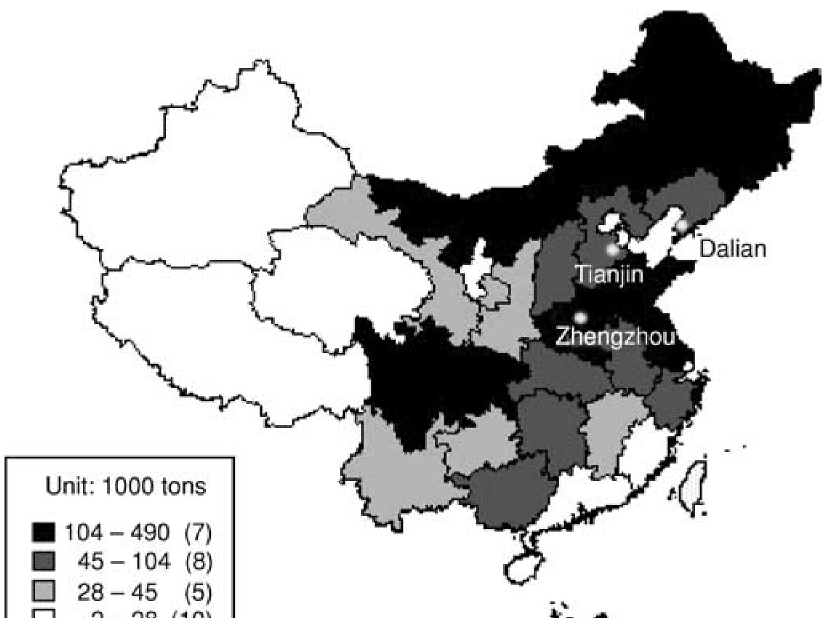

Figure 2 China's soybean production map (2000) and selected markets data. Source: China Bureau of Statistics (2002).

Table 1 Descriptive statistics for the price series

Price series	Mean	Variance	Skewness	Kurtosis
Soybean				
DCE, 1 week†	2.18	0.28	0.62	2.63
DCE, 2 weeks	2.14	0.31	0.80	3.02
DCE, 1 month	2.15	0.28	0.71	2.93
DCE, 2 months	2.18	0.29	0.97	3.10
DCE, 3 months	2.13	0.29	0.91	3.61
DCE, 4 months	2.24	0.30	0.91	3.13
TGWM	2.29	0.26	0.43	2.60
ZGWM	2.20	0.26	1.26	3.73
National	2.32	0.24	1.25	4.68
Wheat				
CZCE, 1 week	1.22	0.16	0.30	2.26
CZCE, 2 weeks	1.22	0.16	0.49	2.46
CZCE, 1 month	1.22	0.15	0.24	2.31
CZCE, 2 months	1.26	0.15	0.14	2.08
CZCE, 3 months	1.29	0.16	−0.13	2.16
CZCE, 4 months	1.32	0.16	−0.17	2.21
TGWM	1.27	0.15	0.36	1.61
ZGWM	1.21	0.15	0.43	2.09
National	1.31	0.15	0.04	1.80

†'1 week' means price taken at 1 week before maturity representing a 1-week forecasting period, and so on. CZCE, China Zhengzhou commodity exchange; DCE, Dalian commodity exchange; TGWM, Tianjin grain wholesale market; ZGWM, Zhengzhou grain wholesale market.

and November. Cash prices taken in the third week of each futures maturity month are used to represent the bi-monthly maturity cash price. Futures market efficiency is tested for six forecasting horizons: 1 week, 2 weeks, 1 month, 2 months, 3 months and 4 months. Therefore, futures prices are taken at the beginning of each forecasting period for each contract.

In summary, we have six cash price series, one for each crop in each market. We also have 12 futures price series, one for each crop and for each forecasting period. The label of each series is listed on the left column of Table 1. The number of observations in each series is 26, the total number of contracts in our dataset. The first four moments of these series are listed in Table 1. Selected price series for wheat and soybean are plotted against contract maturity time in Figures 3 and 4, respectively. These are the cash prices at TGWM and ZGWM and the futures prices at 1 week and 4 months prior to maturity.

5. Results

Each of the price series is first examined for I(1) using both the ADF and the Phillips–Perron procedures in Statistical Analytical Systems. The results indicate each of the price series is I(1), so Johansen's cointegration tests should be performed.[2]

[2] The unit root test results are not reported but are available upon request.

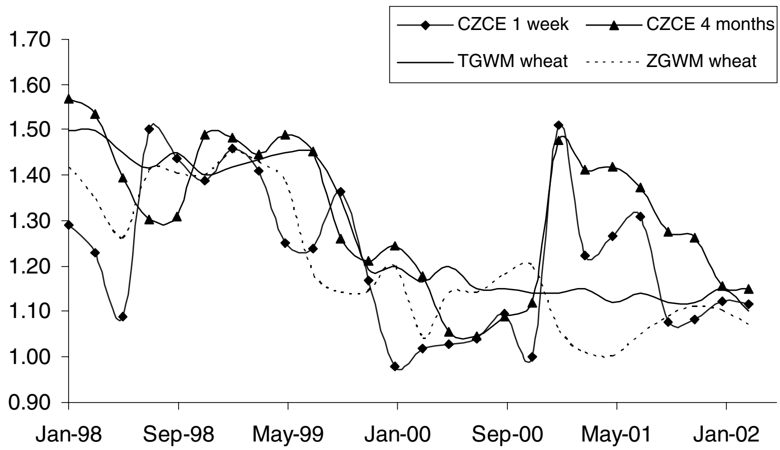

Figure 3 Wheat futures prices for 1-week and 4-month forecasting periods and cash prices at Tianjin and Zhengzhou grain wholesale markets.

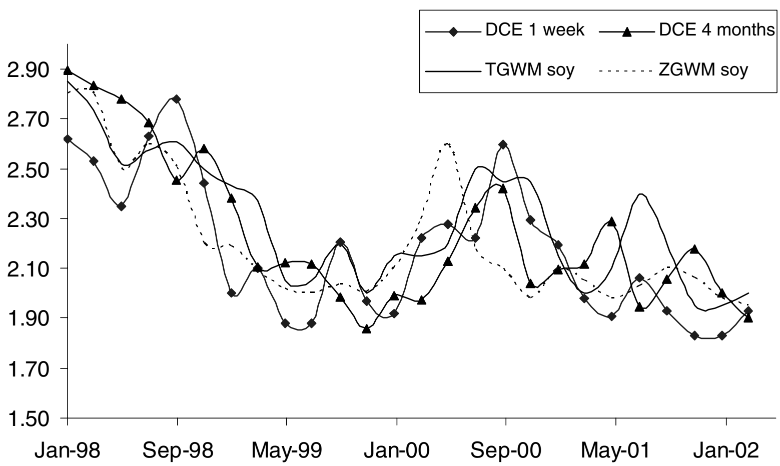

Figure 4 Soybean futures prices for 1-week and 4-month forecasting periods and cash prices at Tianjin and Zhengzhou grain wholesale markets.

Results from alternative levels of k in Equation (2) suggest that the best specification is $k = 1$ for all wheat price pairs and most soybean price pairs. For soybean traded on DCE, $k = 2$ is chosen for the TGWM series for one-, two-, and three-month forecasting periods, for the ZGWM series for the 4-month forecasting period and for the national average series for the 1 week forecast. Autocorrelation and autoregressive conditional heteroskadesticity (ARCH) tests are also conducted on the residuals for each price series and the null hypotheses of no ARCH effect cannot be rejected in general. These results are not reported, but are available upon request.

Two seasonal dummy variables are included in Equation (2) when we test for cointegration between each pair of prices. The growing-season dummy variable takes a value of 1 if the contract is March or May; otherwise it is 0. The harvest-season dummy

Table 2 Johansen cointegration test results for futures and cash prices

	DCE soybean				CZCE wheat			
	λ_{trace}		λ_{max}		λ_{trace}		λ_{max}	
	H_0: $r=0$	H_0: $r=1$	H_0: $r=0$	H_0: $r=1$	H_0: $r=0$	H_0: $r=1$	H_0: $r=0$	H_0: $r=1$
TGWM, 1 week	20.70*	5.47	15.23	5.47	16.72	4.25	12.47	4.25
TGWM, 2 weeks	24.57*	5.52	18.65*	5.92	16.34	3.54	12.79	3.54
TGWM, 1 month	35.18**	5.81	29.37**	5.81	14.28	4.18	10.10	4.18
TGWM, 2 months	34.38**	6.28	28.11**	6.28	13.50	4.19	9.31	4.19
TGWM, 3 months	31.58**	5.28	26.30**	5.28	12.31	4.57	7.47	4.57
TGWM, 4 months	25.06**	7.28	17.78*	7.28	12.07	4.50	7.57	4.50
ZGWM, 1 week	16.91	7.10	9.82	7.10	15.09	3.21	11.88	3.21
ZGWM, 2 weeks	20.83*	7.04	13.79	7.04	13.34	2.32	10.17	2.32
ZGWM, 1 month	23.75*	7.00	16.75*	7.00	11.57	3.45	8.12	3.45
ZGWM, 2 months	36.74**	6.94	29.79**	6.94	11.61	3.33	8.28	3.33
ZGWM, 3 months	37.12**	6.80	30.32**	6.80	13.95	3.38	10.56	3.38
ZGWM, 4 months	42.65**	9.43*	33.22**	9.43*	13.69	3.37	10.32	3.37
National, 1 week	31.63**	6.67	24.96**	6.67	13.27	2.60	10.67	2.60
National, 2 weeks	21.26*	7.62	13.64	7.62	12.28	2.51	9.76	2.51
National, 1 month	20.86*	7.30	13.56	7.30	10.71	3.21	7.50	3.21
National, 2 months	27.94**	9.22	18.72*	9.22	9.37	3.45	5.92	3.45
National, 3 months	33.92**	9.32*	24.60**	9.32*	9.32	3.44	5.88	3.44
National, 4 months	32.96**	9.39*	23.57**	9.39*	9.21	3.65	5.57	3.65
Critical Values (5%)	*19.96*	*9.24*	*15.67*	*9.24*	*19.96*	*9.24*	*15.67*	*9.24*
Critical Values (1%)	*24.60*	*12.97*	*20.20*	*12.97*	*24.60*	*12.97*	*20.20*	*12.97*

*,**null hypothesis is rejected; critical values are taken at a significance level of 5 per cent and 1 per cent, respectively. The listed critical values are from table 1* in Osterwald-Lenum (1992). CZCE, China Zhengzhou commodity exchange; DCE, Dalian commodity exchange; TGWM, Tianjin grain wholesale market; ZGWM, Zhengzhou grain wholesale market.

variable takes a value of 1 if the contract is July or September; otherwise it is 0. The default season is winter (i.e., November and January contracts). No seasonality effects are detected for any wheat prices. For soybean prices, there is no seasonality effect for ZGWM and national cash markets except for the 1-week forecasts, but seasonality effects are detected for all forecast periods in TGWM except for the 3-month forecast.

Both the trace and maximum eigenvalue test statistics given by Equations (3) and (4) are used to test for the number of cointegrating relationships in the price series.

5.1 Soybeans

Cointegration test results for soybean prices are shown in Table 2. Based on the trace test, the null hypothesis of $r = 0$ is rejected at the 5 per cent significance level for all series except for the DCE futures price for 1 week forecast with ZGWM cash price, while the corresponding hypothesis of $r = 1$ cannot be rejected in most cases. Although in a few cases (ZGWM, 4 months; National, 3 and 4 months) the $r = 1$ hypothesis is also rejected at 5 per cent significance level, it cannot be rejected at the 1 per cent level. The same applies to the $r = 0$ hypothesis. The maximum eigenvalue test results are quite consistent with the trace test. This suggests that the futures price of soybeans at

Table 3 Tests of weak exogeneity for cointegrated soybean prices

	Futures		Cash	
	Lr	*P*-value	*Lr*	*P*-value
TGWM, 1 week	1.98	0.16	2.94	0.09
TGWM, 2 weeks	6.24	0.01	3.08	0.08
TGWM, 1 month	0.86	0.36	15.72	0.00
TGWM, 2 months	3.32	0.07	16.34	0.00
TGWM, 3 months	6.19	0.01	19.87	0.00
TGWM, 4 months	3.34	0.07	9.93	0.00
ZGWM, 2 weeks	7.26	0.01	0.00	0.95
ZGWM, 1 month	9.64	0.00	0.01	0.91
ZGWM, 2 months	22.86	0.00	0.00	0.99
ZGWM, 3 months	23.52	0.00	0.05	0.83
ZGWM, 4 months	24.12	0.00	0.00	0.99
National, 1 week	1.67	0.20	8.46	0.00
National, 2 weeks	1.61	0.20	1.55	0.21
National, 1 month	0.74	0.39	1.54	0.21
National, 2 months	7.38	0.01	0.26	0.61
National, 3 months	14.98	0.00	0.05	0.83
National, 4 months	13.91	0.00	0.07	0.79

TGWM, Tianjin grain wholesale market; ZGWM, Zhengzhou grain wholesale market.

DCE for a forecasting period up to 4 months is cointegrated with the cash price in all three markets. The only exception is the ZGWM (cash) with 1 week DCE futures series, where the non-cointegration hypothesis can be rejected when the significance level is relaxed to 20 per cent. These results suggest that a long-run equilibrium relationship exists between the DCE soybean futures price and cash prices in each of the three studied cash markets, TGWM, ZGWM and the national average.

For the cointegrated soybean cash and futures markets, weak exogeneity tests are conducted by testing hypotheses concerning the cointegration loading factor, $\boldsymbol{\alpha}$. The LR test results for all cointegrated price series are reported in Table 3. The weak exogeneity hypothesis is rejected at the 10 per cent significance level in the case of all TGWM cash prices. Interestingly, the fact that the loading factor on the DCE futures price has a higher *P*-value than the loading factor on the TGWM cash price for most of the futures prediction periods, together with the fact that the weak exogeneity hypothesis cannot be rejected at the 5 per cent level for four out of the six series, seems to suggest that whenever a transitory shock occurs, it is the TGWM cash price that adjusts. This is consistent with an efficient market situation in that futures prices Granger-cause cash prices.

However, the hypothesis of weak exogeneity for futures prices relative to the ZGWM cash price is rejected for all forecasting periods and the cash price is found to be weakly exogenous. This means that, unlike DCE futures, ZGWM cash prices are not affected by transitory shocks from the long-run equilibrium. When disequilibrium occurs, the futures price will adjust to restore the equilibrium. This suggests that as cash prices reflect the revealed current supply–demand situation in the ZGWM, futures prices must be influenced by expectations based on information that does not affect the cash market, a situation of short-run inefficiency. This is possible because some information pertaining to areas around Dalian may not affect the Zhengzhou market, a case of location segregation to some extent. The delivery locations of the DCE soybean contracts are all in the Dalian area and some are away from Zhengzhou (see Appendix). Transportation has been a 'bottleneck' in the economic development of China. The main means for grain transportation between Zhengzhou and Dalian is railway freight, which is not only costly but can also involve long delays.

The weak exogeneity results imply that the ZGWM is Granger-causal to DCE, while the DCE is Granger-causal to TGWM. One explanation of this effect in the two soybean cash markets is that the Zhengzhou market is in the centre of a high soybean production area and has the longest history of operation, while Tianjin is a port city with easy access for traders and lower transportation costs.

Dalian Commodity Exchange is the only soybean futures market where price cannot follow both cash markets closely when the two diverge. This can be illustrated by the following example. Suppose both cash market prices are in long-run equilibrium with futures prices. When some information is received about an international soybean market shortage, the futures price will increase. The increase in the futures price breaks the equilibrium between the TGWM price and the futures price. Traders in TGWM ship out soybeans to sell in the international market, so the cash price in TGWM also increases. However, it is difficult for soybean holders in Zhengzhou to ship out to the international market quickly, given high transportation and other transaction costs. Traders still have the same volume of soybeans in supply and demand in the Zhengzhou area and the ZGWM price remains the same. The long-run equilibrium is broken and the futures price will fall back to the equilibrium level after the transitory effect is over. The TGWM cash price will fall after the transitory effect is over.

Cointegration is only a necessary condition for market efficiency. The long-run efficiency in soybean markets also requires the futures price to be an unbiased predictor of the cash price (i.e., $a = 0$ and $b = 1$ in Equation (1)). We have tested three hypotheses: $a = 0$ and $b = 1$ jointly, and each individually. The results are shown in Table 4.

The price series of longer predicting periods (i.e., the 3- and 4-month futures prices) have 'overlapping observation' problems. That is, the period between two adjacent observations is shorter than the prediction period. When overlapping observations are used, serial correlation may affect the distributions of the estimators and make the commonly used hypothesis testing methods unreliable. This overlapping observation problem can sometimes be avoided by reducing the data frequency (Hansen and Hodrick 1980). However, given the small sample size of this study, this is not a feasible solution. To overcome the overlapping observations problem, we use the fully modified ordinary least-squares (FM-OLS) model introduced by Phillips and Hansen (1990) for the 3- and 4-month prediction periods. A modified version of the Wald test is then used to test for efficiency. There are no overlapping observation problems for the 1-week, 2-week, 1-month and 2-month futures prices.

Although estimates and tests based on maximum likelihood and least squares can be different, the two sets of results are quite consistent in this study. The joint null hypothesis of $a = 0$ and $b = 1$ is rejected for all of the national prices and half of the TGWM prices at a significance level of 10 per cent, but cannot be rejected for any

Table 4 Small sample tests of restrictions on cointegrating vectors for soybean

	Estimates		H_0: $a = 0$ and $b = 1$		H_0: $a = 0$		H_0: $b = 1$	
	A	b	$Lr/$W†	P-value	$Lr/$W	P-value	$Lr/$W	P-value
Non-overlapping data likelihood-ratio test								
TGWM								
1 week	−0.47	1.16	4.43	0.109	1.06	0.303	0.65	0.420
2 weeks	−0.55	1.17	7.01	0.030	1.37	0.242	0.75	0.386
1 month	−0.63	1.22	12.71	0.002	5.07	0.024	3.50	0.061
2 months	−0.61	1.23	11.58	0.003	4.76	0.029	3.47	0.062
ZGWM								
2 weeks	0.04	0.94	2.04	0.361	0.00	1.000	0.04	0.841
1 month	0.04	0.95	2.58	0.275	0.01	0.920	0.06	0.806
2 months	0.06	0.95	4.26	0.119	0.06	0.806	0.21	0.647
National average								
1 week	−1.47	1.59	12.65	0.002	8.03	0.005	6.98	0.008
2 weeks	−1.32	1.52	5.98	0.050	2.43	0.119	1.92	0.166
1 month	−1.18	1.46	6.74	0.034	3.00	0.083	2.36	0.124
2 months	−0.51	1.16	11.13	0.004	1.38	0.240	0.71	0.399
Overlapping data Wald test								
TGWM								
3 months	−0.37	1.18	2.47	0.290	0.49	0.486	0.76	0.383
4 months	0.25	0.94	2.09	0.351	0.43	0.510	0.12	0.730
ZGWM								
3 months	0.24	0.89	0.39	0.821	0.32	0.573	0.35	0.552
4 months	0.56	0.73	2.21	0.330	1.52	0.217	1.77	0.183
National average								
3 months	−0.61	1.30	7.78	0.020	3.21	0.073	2.26	0.132
4 months	−0.98	1.69	8.40	0.015	6.99	0.008	6.08	0.014

†The $Lr/$W columns report the log likelihood-ratio statistics for the non-overlapping data series, and the Wald statistics for the overlapping data series. TGWM, Tianjin grain wholesale market; ZGWM, Zhengzhou grain wholesale market.

ZGWM and the other half of the TGWM price series (the 1-week, 3- and 4-month series). This suggests the soybean futures price is an unbiased predictor for ZGWM cash prices in the long-run, but not a very good predictor for national prices. The results for the TGWM prices are ambiguous. However, the unbiasedness assumption is too strong to imply market efficiency. As discussed, the unbiasedness hypothesis may be rejected with the existence of a risk premium or a transportation cost even when the market is efficient. Therefore, more inferences can be drawn from the separate tests of $a = 0$ and $b = 1$.

The separate null hypothesis of $b = 1$ can be rejected for only two cases (national 1-week and 4-month) at 5 per cent or higher significance levels. In addition to these two cases, the TGWM 1- and 2-month price series also reject $a = 0$. Furthermore, compared to the P-values associated with a test of $a = 0$, the corresponding P-values associated with a test of $b = 1$ are consistently higher for the cash prices in these four cases, showing it is easier to reject the $a = 0$ hypothesis. This suggests that the bias of futures prediction is primarily caused by a fixed cost from carrying and transporting the commodity. Market efficiency in the long run cannot be rejected in general.

5.2 Wheat

Results of cointegration tests on wheat price data are also reported in Table 2. None of the test statistics are large enough to reject the null hypothesis of $r = 0$ at the 5 per cent significance level for any series. This shows that the wheat futures price is not cointegrated with cash prices, indicating no long-run equilibrium relationship between the wheat futures market and cash market for any forecasting horizons and any cash markets.

As discussed earlier, the lack of cointegration may be caused by non-stationary components of transportation and carrying costs, including factors like the interest rate, risk premiums, convenience yields and physical storage costs. Because there are many futures contract delivery locations in Zhengzhou, where the major cash wholesale market is also located, transportation costs should play only a small role in the cash-futures price disequilibrium between ZGWM and CZCE. Interest rate effects should also be small for the reason discussed earlier. Effects from other factors in the carrying cost should also be very small when the futures contracts get close to maturity. However, cointegration relationships are clearly rejected even among the price series for 1 week and 2 weeks prior to maturity. This indicates that China's wheat futures market is inefficient.

One major factor that may account for this market inefficiency is over-speculation or market manipulation, of which a number of cases have been observed. In a mature market economy where information is widely available and traders are rational, speculation behaviour will drive away profits, reduce arbitrage opportunities and contribute to market efficiency. However, in China during the 1990s, the flow of information was not very efficient. A few large traders did not passively respond to price in their speculating, but tried to actively influence the price. In addition, many smaller traders simply followed them, which made it easier for the larger traders to manipulate the market. Such cases have been discussed by Williams *et al.* (1998) and Lien and Yang (2004). As a result, some large traders could create a favourable market situation for themselves at the expense of small traders. The market was also very volatile during that period. Although there might also be over-speculation problems in the DCE soybeans market, it is not as serious as in the CZCE wheat market.

Different government policies for the two commodities might be another factor that affects the performance of the wheat futures market relative to the soybean futures market. As the most important food grain, wheat production is closely associated with national food security – a high priority concern of the government in making policy. For this reason, wheat is still regulated by the government directly or indirectly. For example, wheat imports and exports are tightly controlled by the government. Although the tariff rate on wheat imports has been as low as 1 per cent since 1999, the import quota was highly restrictive during this period. All imports had to go through the China National Cereals, Oils and Foodstuffs Import and Export Corporation. In comparison, soybean is used as feed and the market is less regulated. Soybean imports are no longer controlled and the import volume has increased significantly in the last decade.

6. Conclusion

After 9 years in operation, the agricultural commodity futures markets in China are among the most active in the world. In this paper, we perform formal statistical tests on the efficiency of futures markets for two major agricultural commodities, wheat and soybean.

Results based on Johansen's cointegration tests and likelihood-ratio tests suggest that long-run equilibrium relationships exist between the DCE soybean futures price and the ZGWM cash price, the TGWM cash price and the national average cash price. The long-run efficiency of these markets is also implied by the soybean futures price in terms of its predictability on the ZGWM cash price (and to a lesser extent, the TGWM). Weak exogeneity tests reveal the DCE is short-run efficient for TGWM but inefficient for ZGWM. This suggests that the ZGWM soybean price is causal in the long run, while the TGWM tends to follow with the futures market facilitating the flow of information. Although the long-run efficiency of the soybean futures market cannot be rejected for TGWM, traders still need to be aware of the fact that the DCE futures price may not be a good indicator for ZGWM cash prices in the short run.

In contrast to the soybean futures market, the wheat futures market in China is still inefficient. Wheat futures prices are not cointegrated with any wheat cash prices. Market manipulation by large traders and government regulation may account for the inefficiency observed during the period of this study.

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Appendix

Trading rules of the wheat and soybean futures markets in China

	Wheat	Soybean
Commodity	Hard white winter wheat	Yellow soybean (non-genetically modified organism)
Trading unit	10 metric ton/contract	10 metric ton/contract
Maturity month	January, March, May, July, September and November	January, March, May, July, September and November
Margin account	5%	5%
Transaction fee	2 yuan/contract	4 yuan/contract
Last trading day	The seventh to last trading day of the contract's maturity month	The 10th trading day of the maturity month
Delivery days	Any trading day of the maturity month until the last trading day	Any trading day of the maturity month until 10 days after the last trading day
Delivery location	22 locations in the production area of the country, five in the same province as CZCE, one in Tianjin	25 locations, all in Dalian, the same city as DCE
Delivery grade	Grade 2, satisfying the national standard GB1351-1999	Grade 3, satisfying the national standard GB5490-5539
Substitutable grades	Grades 1 and 3, price adjusted	Grades 1, 2 and 4, price adjusted
Exchange market	CZCE	DCE
Maximum transactions	2000/day per trading agent	1000/day per trading agent 400/day per trader
Daily maximum price change	±3% of the previous trading day's settlement price	±3% of the previous trading day's settlement price
Exchange membership	400 000 yuan initial fee 20 000 yuan annual fee	500 000 yuan initial fee 20 000 yuan annual fee

Sources: China Zhengzhou commodity exchange (CZCE) web site, http://www.czce.com.cn/ [accessed 10 October 2003], and Dalian commodity exchange (DCE) web site, http://www.dce.com.cn/ [accessed 10 October 2003].