IS CHINA'S AGRICULTURAL FUTURES MARKET EFFICIENT?

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September 3, 2003

Paper prepared for presentation at the 25th International Conference of Agricultural Economists, August 16-22, 2003, Durban, South Africa

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Abstract

In this paper, we study the efficiency of the Chinese wheat and soybeans futures markets and assess the conditions in agricultural commodity futures and cash markets in China. Formal statistical tests are conducted through Johansen's cointegration approach to identify the long-term equilibrium relationship between futures and cash markets.

Three different cash prices from Zhengzhou Grain Wholesale Market, Tianjin Grain Wholesale Market, and the national average wholesale price are used. The wheat futures price from China Zhengzhou Commodity Exchange and soybeans futures price from Dalian Commodity Exchange with different forecasting horizons ranging from one week to six months are also used.

Results suggest that a long-term equilibrium relationship between the futures price and cash price for soybeans has been established. A weak short-term efficiency of the soybean futures market is revealed. The futures market for wheat is inefficient. The relative inefficient wheat market may be caused by over-speculation and government intervention, because wheat is the staple food in China and the government has more control over it than soybeans. Another reason is geographic proximities between the cash market in Tianjin and both the soybean production area and the futures market in Dalian.

Key words: grain, futures market, efficiency, China, cointegration test

Introduction

China started a significant economic reform in 1978, transforming its centrally planned economy to 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). After three years of successful operation of forward contracts, the China Zhengzhou Commodity Exchange (CZCE) was established in 1993 basing its operation on the ZGWM and specializes in the trading of agricultural commodity futures contracts.

The first futures commodity traded in the CZCE was mung bean and its trading had flourished in the earlier years. Because mung bean is not a major agricultural product, the active trading was almost exclusively a result of speculation. As a result, mung bean futures have largely been phased out of the market by a recently increased margin account of 20%. On the other hand, wheat futures trading in CZCE has shown significant growth. Over 14 million contracts were traded in 2001, compared to less than 200 thousand 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 specializes in trading metals, while both the CZCE and the DCE are for agricultural commodities: primarily wheat in CZCE and soybeans in DCE. Now, the DCE is the second largest soybean futures market in the world after CBOT, with trading volume 3.8 times higher than that in the Tokyo Commodity Exchange (Food China, 2001).

The goal of this study is to test the efficiency of the futures markets for agricultural commodities in China. An efficient market is one in which prices always "fully reflect" available information and where no traders in the market can make a sure profit. In other words, an efficient commodity futures market can provide effective signals for the spot market price and eliminates the possibility that profit can be guaranteed as part of the trading process. This price reflects the equilibrium value for suppliers and demanders in the market.

The study of market efficiency in agricultural commodity futures markets is important to both the government and the producers/marketers in China. From the government policy point of view, an efficient market means a better alternative to market interventions such as imposing price stabilization policies. For processors/marketers, it provides a reliable forecast of spot prices in the future to allow them effectively manage their risks in the production or marketing process. It is also the interest of international market participants from countries like Canada, US, Australia, and EU, who are the major grain exporters to China. Thus this study can provide international exporters/importers of agricultural commodities 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 China futures market are rare. Most of existing studies are focused on legislative regulation and market development and improvement and very few have investigated the agricultural commodity futures prices quantitatively.

In this study we use a quantitative approach to test the efficiency of agricultural futures markets. Specifically, we study or examine (1) the long-run equilibrium relationship between the futures price and the cash price; (2) the efficiency of futures market as a predictor of cash market, and (3) the relative performance of futures price in forecasting different cash prices. We focus on the two major agricultural commodities traded in China: wheat on the CZCE and soybeans on the DCE.

Literature Review

There are few studies on futures market in China. Most of the publications about these markets are descriptive analyses with emphases on legislative and/or other developing issues. Such examples include papers written by Tao and Lei (1998); and Fan, Ding, and Wang (1999). The historical development of futures markets in China can be found in Yao (1998).

Williams, et al. (1998) described the development and the characteristics of mung bean trading in the CZCE. By analyzing the price spreads between different contracts in the same crop year, they found that the conditions for arbitrage existed on the CZCE. The existence of arbitrage is a sign of inefficiency. Durham and Si (1999) examined the relationship between the DCE and the CBOT soybean futures prices. Using the law of one-price models, they conclude that the soybean futures price in DCE is influenced by CBOT price, but that the relationship between the two cannot be well represented by one single model.

There are numerous studies, both theoretical and empirical, that analyze the efficiency of futures markets in developed countries like the US. We refer to Fama (1970) for a thorough summary of the early works on market efficiency testing. Recently, a simple linear regression model was used by Bigman, Goldfarb, and Schechtman (1983) to test the efficiency of wheat, corn and soybeans trading at the CBOT. Based on F tests they conclude that futures prices generally provide inefficient estimates of the spot price at maturity. Later, Maberly (1985), Elam and Dixon (1988), and Shen and Wang (1990) pointed out that the result is invalid based on such conventional F tests when the price series are non-stationary.

The development of cointegration theory by Engle and Grange (1987) provided a new technique for testing market efficiency. Aulton, Ennew, and Rayner (1997) re-investigated the efficiency of UK agricultural commodity futures markets using the cointegration methodology. The cointegration method can effectively account for the nonstationarity but no strong inferences can be drawn for the parameters, which are the central point of the efficiency tests (Lai and Lai, 1991). Following Engle and Grange, 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 autoregressive (VAR) model that allows for possible interactions in the determination of spot prices and futures prices. Lai and Lai (1991) suggested use of Johansen's approach to test for market efficiency and illustrated the procedure with an example of the forward currency market in the US. The Johansen's approach has been widely applied since then (Fortenbery and Zapata, 1993; Mckenzie and Holt, 1998; and Kellard, et al., 1999).

In this paper, the Johansen approach is used to test the efficiency of the two well-traded agricultural commodities in China: wheat and soybean. The relative performances of futures markets in forecasting different cash markets are also evaluated.

Methodology

A nonstationary time series is said to be integrated in order one, often denoted by *I(1)*, if the series is stationary after the first-order differencing. An (n x 1) vector time series $\boldsymbol{Y}_t$ is said to be cointegrated if each of the series taken individually is *I (1)* while some linear combination of the series AY_t is stationary for some nonzero 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 futures price taken at i periods before the contract matures at time t, where i is the number of periods interested. 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 exist a and b such that $\boldsymbol{z}_t$ is stationary with mean 0:

$$z_t = S_t - a - bF_{t-i}. \qquad (1)$$

If both S_t and F_{t-i} are *I (1),* a condition that usually holds for prices, the vector process (S_t, F_{t-i}) is cointegrated. This cointegration between S_t and F_{t-i} is a necessary condition for market efficiency (Lai and Lai, 1991). Cointegration ensures that there exists a long-run equilibrium relationship between the two series. 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 the movement of the cash price.

In addition to cointegration, market efficiency also requires an unbiased forecast of futures price on cash price, i.e., $a = 0$ and $b = 1$ in (1). Therefore, the market efficiency should be tested in two steps: first to examine the cointegration relationship between the two price series S_t and F_{t-i}; if cointegration exists then the parameters restriction $a = 0$ and $b = 1$ is tested. The second step may consist of multiple tests: $a = 0$ and $b = 1$ jointly or each individually. The constraint $b = 1$ is a more important indicator for market efficiency, because a is non-zero under the existence of risk premium and/or transportation costs even when the market is efficient. The cointegration relationship and the parameter restrictions can be tested using Johansen's approach and the likelihood ratio test, respectively, as outlined below.

Cointegration tests

Before testing for cointegration, each individual price series should be examined for $I(1)$ first. Augmented Dickey-Fuller (ADF) and the Phillips-Perron unit root tests are the common methods (Chowdhury, 1991; Lai and Lai, 1991), and are used here. If both the futures price and cash price are $I(1)$, Johansen's cointegration tests can then be conducted. Consider a general kth order VAR model:

$$\Delta \boldsymbol{Y}_t = \boldsymbol{D} + \Pi \boldsymbol{Y}_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta \boldsymbol{Y}_{t-i} + \boldsymbol{\varepsilon}_t \qquad (2)$$

where Y_t is an $(n \times 1)$ vector to be tested for cointegration, and $\Delta \boldsymbol{Y_t} = \boldsymbol{Y_t} - \boldsymbol{Y_{t-1}}$; $\boldsymbol{D}$ is the deterministic term which may take different forms such as a vector of zeros or non-zero constants depending on properties of the data to be tested; $\mathbf{\Pi}$ and $\mathbf{\Gamma}$ are matrices of coefficients; and k is chosen so that ε_t is a multivariate normal white noise process with a mean 0 and a finite covariance matrix.

The cointegration relationship can be detected by examining the rank of $\mathbf{\Pi}$, because the number of cointegration vectors equals the rank of $\mathbf{\Pi}$. In particular, the 0 rank or $\mathbf{\Pi} = \mathbf{0}$, implies no cointegration. In a bi-variable case, i.e., $n = 2$, the two variables are cointegrated only if the rank of Π equals 1 (Johansen and Juselius, 1990).

Johansen (1988) suggested two test statistics to test the null hypothesis that there are at most r cointegration vectors. The null hypothesis can be equivalently stated as the rank of the coefficient matrix, Π, is at most *r*, for *r = 0, 1, ..., n-1*. The two test statistics are based on trace and maximum eigenvalues, respectively,

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

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

where $\hat{\lambda}_1 \ldots \hat{\lambda}_r$ 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 ***1*** respectively. The critical values are provided by Osterwald-Lenum (1992).

In our test for efficiency of futures market, $\boldsymbol{Y_t} = (S_t, F_{t-i})'$, *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 cointegration. On the other hand, if *r* = 0 is rejected, and *r* = 1 cannot be rejected, we will conclude that there is a cointegration relationship.

Tests of Restrictions on Cointegration Vectors

Inefficiency can be concluded if the futures price and the cash price are not cointegrated since cointegration is a necessary condition for market efficiency. If the futures price and the cash market price are cointegrated, we can then test restrictions on the parameters in (1). Cointegration implies that there exists a cointegration vector $\boldsymbol{\beta}$ such that $\boldsymbol{\beta}'\boldsymbol{Y}_t^*$ is stationary, where in equation (1), $\boldsymbol{\beta}' = (1, -b, -a)$ and $\boldsymbol{Y}_t^* = (S_t, F_{t-i}, 1)'$, so that $z_t = \boldsymbol{\beta}'\boldsymbol{Y}_t^*$ is stationary. The market efficiency hypotheses can then be tested by imposing restrictions on the cointegration vector $\boldsymbol{\beta}$. For example, the hypothesis of $a=0$ and $b=1$ can be expressed as $\boldsymbol{\beta}' = (1, -1, 0)$. We can then apply the standard likelihood ratio test in this case. Specifically, the test statistics can be expressed by the canonical correlations as (Johansen and Juselius, 1990):

$$L_r = T \sum_{i=1}^{r} \ln\{(1-\lambda_i^*)/(1-\hat{\lambda}_i)\} \qquad (5)$$

where $\lambda_1^* \ldots \lambda_r^*$ 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 $\chi 2$ distribution with degree of freedom equaling the number of restrictions imposed.

Data

Two agricultural commodity futures markets are included in this study: the CZCE for wheat and the DCE for soybeans. Two cash markets, the Zhengzhou Grain Wholesale Market (ZGWM) and the Tianjin Grain Wholesale Market (TGWM), are chosen to test the efficiency of futures markets for both wheat and soybeans. The ZGWM is located in Central China – the major wheat production area. TGWM, established in 1994, is another major agricultural wholesale market in China. Another cash price, the national average price, is also included in the tests. The national average price is calculated based on price from 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 of wheat and soybeans during the period of January 1998 to March 2002 are provided by the CZCE and the DCE respectively. Cash prices are obtained from CNgrain online database (http://www.Cngrain.com). There are six contracts each year for both wheat and soybeans futures: January, March, May, July, September and November. Cash prices are taken at the third week of each maturity month of the six futures contracts. Futures market efficiency is tested for six forecasting horizons, ranging from one week to six months. Accordingly, futures prices are taken at one week, two weeks, one month, two months, four months and six months prior to the maturity of each contract.

In summary, we have six cash price series, one for each crop in each market consisting of prices taking at the third week of all maturity months. We also have twelve futures price series, six for each crop. For either crop, each futures price series consists of prices taken at a particular period prior to the cash price observation week, which is assumed to be the maturity week. The number of observations of each series is the total number of contracts, 26, in our data set.

Results

Each of the price series is first examined for *I (1),* which is carried out in two steps. The results of both ADF and the Phillips-Perron unit root tests suggest the existence of unit root in each of the price series. Further tests indicate that all the price series data are stationary after the first-order differencing. (The test results are not reported, but are available upon request.) Therefore we conclude that each of the price series is *I (1)*, and proceed to the next step, Johansen's cointegration tests.

Soybeans

Cointegration testing results for soybean prices are shown in Table 1. The null hypothesis of $r = 0$ is rejected at a significant level of 0.05 by both test statistics for each of the nine soybean series, while the corresponding hypothesis of $r = 1$ cannot be rejected. This suggests that the futures price of soybeans taken at up to four months before its maturity is cointegrated with the cash price in the TGWM, and the futures price of soybeans, taken at up to two months prior to its maturity, is cointegrated with its national average cash price. These results suggest that a long-run equilibrium relationship has been established between the soybean futures price and cash price of the TGWM, and between the futures price and its national average cash price. These results also indicate that the futures price has a closer relationship with the cash price in a shorter forecasting horizon than in a longer one. This is reasonable in that the futures price contains better information about the supply and demand of the commodity when it gets closer to its maturity. However, soybean futures price is not cointegrated with its cash price in the ZGWM. This is different from what was expected, because the ZGWM was established earlier, and it is larger and more influential than the TGWM. There are at least two factors that may explain the disparity. First, Tianjin is located closer to the major soybean production area --- Northeastern China, and the soybean futures market (Dalian) is right across the bay. This geographical closeness may help to smooth the flow of information. Secondly, transportation has been a critical factor in the circulation of agricultural products in China. Because Tianjin serves as large port for both domestic and imported/exported grain transportation, convenient transportation facilities there make the price more responsive to market demand and supply.

Besides cointegration, efficiency 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 2. The null hypothesis of $a = 0$ and $b = 1$ is rejected in every case at a significance level of 0.01 except for the 1 week and 4 month prices of TGWM, which are also rejected at 0.05 level. This means the soybean futures price is not an unbiased predictor for cash prices for either market at any time. However, the unbiasedness assumption is too strong to imply market efficiency. As discussed earlier in the paper, the unbiasedness hypothesis may be rejected with the existence of a risk premium and/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 null hypothesis of $a = 0$ is rejected for all cases at 0.05 or higher significant level except for the one week forecasting horizon for Tianjin cash price, which is also rejected at 0.1 level. This indicates that there exists a non-zero risk premium from traders in the futures market and/or a transportation cost between Dalian and Tianjin. The null hypothesis of $b = 1$ cannot be rejected at 0.1 level for the one week forecasting of TGWM. This indicates the soybean futures market is efficient in the very short-term. Notice, although $b = 1$ is still rejected at 0.05 or even 0.01 for all other cases, the p-values are generally larger than those corresponding cases for $a = 0$. This suggests that the market efficiency is less likely to be rejected than the zero risk premium and transportation cost, and the latter is the main contributor to the rejection of joint test hypothesis.

Wheat

Results of cointegration tests on wheat price data are also reported in Table 1. None of the test statistics is large enough to reject the null hypothesis of $r = 0$ at 0.05 significant level for any series. This shows that the wheat futures price is not cointegrated with cash prices. This result holds for all forecasting horizons and all cash markets. There is no long-run equilibrium relationship between the wheat futures market and any of its cash markets. Since cointegration is a necessary condition for futures market efficiency, we can conclude that China's wheat futures market is inefficient. One major factor that may account for the market inefficiency is over-speculation or market manipulation. There have been a number of cases of market manipulation since the establishment of the futures market. Although there might be also over-speculation problems in the Dalian soybeans market, it is not as serious as in the CZCE wheat market (Durham and Si, 1999). Different government policies on the two commodities might be another factor that affects the relative performance of the wheat futures market and the soybeans futures market. As the most important food grain, wheat is one of the commodities mostly related to national food security—a high priority concern of the government in making policy. For this reason, such commodities are still regulated by the government directly or indirectly. For example, wheat import and export are tightly controlled by the government. On the other hand, soybeans are used as feed and oilseeds and the market is less regulated. Soybean imports are no longer controlled and imports of the product have increased significantly in recent years.

Summary and Conclusions

After nine years in operation, the agricultural commodity futures markets in China are among the most active ones in the world. However, few quantitative studies have been conducted to evaluate the efficiency of these futures markets. In this paper, we perform formal statistical tests on the efficiency of futures market for two major agricultural commodities, wheat and soybeans.

Results based on Johansen's cointegration test suggest that long-run equilibrium relationships between the DCE soybean futures price and the TGWM cash price, and between the soybean futures price and the national average cash price have been established. A weak short-term efficiency is also implied by the data for the soybean futures market in terms of predicting the price on the Tianjin cash market, despite of the existence of a risk premium from traders in the futures market and some transportation cost between the futures and the cash market. The geographic proximities between the cash market in Tianjin and both the soybean production area and the futures market in Dalian can partially explain the better performance of DCE in predicting cash price of TGWM than that of ZGWM. However, the wheat futures market in China is still inefficient. The wheat futures market is not cointegrated with any wheat cash markets. Over-speculation and government policy may account for the inefficiency.

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Table 1 Statistics of Johansen's Cointegration Tests

	Soybeans				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*
Tianjin, 1 week	21.63*	5.11	16.52*	5.11	12.64	3.73	8.91	3.73
Tianjin, 2 weeks	25.19*	5.11	20.08*	5.11	12.51	3.01	9.50	3.01
Tianjin, 1 month	35.18*	5.81	29.37*	5.81	11.68	3.30	8.39	3.30
Tianjin, 2 months	34.38*	6.28	28.11*	6.28	13.37	3.64	9.73	3.64
Tianjin, 4 months	27.63*	6.20	21.43*	6.20	11.44	4.03	7.41	4.03
Tianjin, 6 months	16.62	4.19	12.43	4.19	13.89	4.40	9.49	4.40
Zhengzhou, 1 week	19.23	5.00	14.23	5.00	10.63	2.27	8.36	2.27
Zhengzhou, 2 weeks	18.47	5.34	13.13	5.34	9.06	2.25	6.81	2.25
Zhengzhou, 1 month	17.02	5.05	11.97	5.05	8.37	2.42	5.96	2.42
Zhengzhou, 2 months	17.26	5.36	11.90	5.36	8.66	2.56	6.11	2.56
Zhengzhou, 4 months	13.53	4.76	8.77	4.76	9.80	2.78	7.02	2.78
Zhengzhou, 6 months	19.49	6.94	12.54	6.94	14.17	2.99	11.18	2.99
National, 1 week	31.63*	6.67	24.96*	6.67	8.94	1.99	6.95	1.99
National, 2 weeks	24.31*	5.58	18.74*	5.58	8.95	1.87	7.09	1.87
National, 1 month	23.74*	5.54	18.21*	5.54	8.18	2.03	6.15	2.03
National, 2 months	22.37*	5.63	16.75*	5.63	9.89	2.22	7.67	2.22
National, 4 months	12.55	2.96	9.59	2.96	9.33	2.23	7.11	2.23
National, 6 months	19.68	4.33	15.35	4.33	11.60	2.51	9.08	2.51
Critical Values	***19.96***	***9.24***	***15.67***	***9.24***	***19.96***	***9.24***	***15.67***	***9.24***

Note: An * indicates that the null hypothesis is rejected; critical values are taken at a significance level of 0.05.

Table 2 Tests of Restrictions on Cointegration Vectors for Soybeans

	Estimates		H_0: *a=0* and *b=1*		H_0: *a=0*		H_0: *b=1*	
	a	b	Lr	P-Value	Lr	P-Value	Lr	P-Value
Tianjin, 1 week	-0.65	1.248	7.26**	0.026	3.24*	0.072	2.48	0.115
Tianjin, 2 weeks	-0.92	1.348	11.65***	0.003	6.26**	0.012	4.89**	0.027
Tianjin, 1 month	-0.63	1.224	16.52***	0.000	6.76***	0.009	4.67**	0.031
Tianjin, 2 months	-0.61	1.225	15.05***	0.000	6.35**	0.012	4.63**	0.030
Tianjin, 4 months	-0.63	1.249	8.95**	0.011	4.12**	0.042	4.23**	0.040
National, 1 week	-1.47	1.591	16.45***	0.000	10.74***	0.001	9.33***	0.002
National, 2 weeks	-2.32	1.953	14.05***	0.001	10.86***	0.001	9.92***	0.002
National, 1 month	-1.80	1.728	13.86***	0.001	10.38***	0.001	9.38***	0.002
National, 2 months	-1.75	1.714	13.33***	0.001	9.95***	0.001	9.07***	0.003

Notes: 1. An * indicates that the null hypothesis is rejected at a significance level of 0.10.
2. An ** indicates that the null hypothesis is rejected at a significance level of 0.05.
3. An ***indicates that the null hypothesis is rejected at a significance level of 0.01