The efficiency of the futures market for agricultural commodities in the UK

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Abstract

This paper uses cointegration procedures to test for agricultural commodity futures market efficiency in the UK. Cointegration between spot and futures prices is a necessary condition for market efficiency where these prices are characterised by stochastic trends (Lai and Lai 1991). In addition, acceptance of the 'unbiasedness hypothesis' requires that the spot and lagged futures prices are cointegrated with the cointegrating vector (1, -1). Alternatively, Brenner and Kroner (1995) use a no-arbitrage cost-of-carry model to argue that the existence of cointegration between spot and futures prices depends on the time series properties of the cost-of-carry. According to Brenner and Kroner (1995), a tri-variate cointegrating relationship (the BK hypothesis) should exist among the spot price, the lagged futures price and the lagged interest rate (that component of cost-of-carry most likely to be non-stationary). These variables should be cointegrated with a cointegrating vector (1, -1, 1). Kellard (2002) finds that both bi-variate and tri-variate cointegrating relationships are found in a sample from the wheat futures market in the UK, and thus the so-called "cointegration paradox" emerges. As Kellard (2002) points out this paradox exists because it is theoretically impossible for two variables to be cointegrated with each other while simultaneously being cointegrated with a third variable. Using a larger sample of wheat futures market prices from LIFFE both the 'unbiasedness hypothesis' and the 'BK hypothesis' are examined. The results indicate that the 'BK hypothesis' should be rejected.

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1.   Introduction

The efficiency of commodity futures markets has been an issue of debate for sometime. As Wang and Ke (2003) argue, an efficient commodity futures price should act as an effective and 'unbiased' predictor for the future spot price and reflect the equilibrium value of supply and demand in the market. In other words, there should be no guaranteed profitable arbitrage opportunities generated by the trading process. In recognition that the spot and futures prices usually contain unit roots (Shen and Wang, 1990), cointegration between spot and futures prices is conventionally regarded as one of the necessary conditions for market efficiency (Lai and Lai 1991). It ensures at least a long-run equilibrium relationship between the two prices. Otherwise, the spot and futures prices will drift apart without bound, so that the futures price provides little information about the future spot price. In addition, acceptance of the 'unbiasedness hypothesis' requires that the spot and lagged futures prices are cointegrated with the cointegrating vector (1, -1) and also that there is an absence of short-run dynamics.

The empirical evidence with regard to the efficiency of futures markets is somewhat mixed. Some studies find evidence of efficiency (e.g., Kellard et al, 1999), while others do not (e.g., Baillie and Myers, 1991). The possible explanations for the mixed findings obtained in empirical testing of futures market efficiency include, the difference in time periods analysed and in the methodology used (Jumah *et al*. 1999), the presence of a risk premium (Krehbiel and Adkins, 1993), the inability of the futures price to reflect all publicly available information (Beck, 1994), the inefficiency of agents as information processors (Kaminsky and Kumar, 1990), and the neglect of interest rates (the nonstationary part of storage cost) which play an important role as they enter arbitrage relationships between spot and futures prices (Brenner and Kroner, 1995).

Among these explanations for the differing conclusions reached by empirical studies on the issue of futures market efficiency, the Brenner and Kroner (1995) (BK) explanation has

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attracted a lot of attention. Brenner and Kroner (1995) use a no-arbitrage cost-of-carry model to argue that the existence of cointegration between spot and futures prices depends on the time series properties of the cost-of-carry. As demonstrated by Park and Phillips (1989), a stationary variable can be omitted from a cointegrating regression without affecting either the consistency of the coefficient estimates or the power of the statistical hypothesis testing procedures. Thus the conventional test for market efficiency may find that spot and futures prices are cointegrated with the cointegrating vector (1, -1) if the cost-of-carry is stationary; otherwise, according to BK, a tri-variate cointegrating relationship (the BK hypothesis) should exist among the spot price, the lagged futures price and the lagged interest rate (that component of cost-of-carry most likely to be non-stationary) in what is termed a 'commodity arbitrage' model. These variables should be cointegrated with a cointegrating vector (1, -1, 1).

Empirical studies, such as Jumah *et al.* (1999), Kellard et al (1999) and McKenzie *et al.* (2002), provide support for the BK hypothesis. However, Kellard (2002) finds that both bi-variate and tri-variate cointegrating relationships exist in a small sample from the wheat futures market in the UK, and thus the so-called "cointegration paradox" emerges. As Kellard (2002) points out his paradox exists because it is theoretically impossible for two variables to be cointegrated with each other while simultaneously being cointegrated with a third variable. Kellard (2002) puts forward an explanation for his finding but doubts the ability of cointegration-based tests to distinguish between the 'unbiasedness hypothesis' and the 'BK hypothesis'.

This paper uses a larger sample from LIFFE to examine the 'unbiasedness hypothesis' and the 'BK hypothesis' for the wheat futures market in the UK in order to shed further light on the paradox uncovered by Kellard (2002). In section 2 an overview of the unbiasedness hypothesis and the BK framework is provided. A description of the dataset is given in section 3. The results of the tests of wheat futures market efficiency are presented in section 4. Conclusions, in section 5, complete the paper.

2.   The Unbiasedness Hypothesis and the BK Hypothesis

The unbiasedness hypothesis and the no-arbitrage cost-of-carry (or Brenner and Kroner (BK)) hypothesis are alternative models for examining the efficiency of futures markets. To some extent these models can be viewed as complementary rather than competing. In the following both models are briefly discussed.   The unbiasedness hypothesis is, from a theoretical point of view, a joint assumption of both market efficiency and risk neutrality (Beck, 1994) and it is represented as follows:

$$S_t = \alpha + \beta_1 F_{t-1} + \beta_2 \pi_{t-1} + v_t \qquad (1)$$

where S_t and F_{t-1} are the natural logarithms of the spot and futures prices at time t and t-1, π_{t-1} is the zero mean risk premium and v_t is white noise. Given that spot and futures prices are usually found to be nonstationary and integrated of order one (Shen and Wang, 1990) a necessary condition for market efficiency, which does not require the explicit identification of the risk premium, is the existence of cointegration between spot and lagged futures prices with a cointegrating vector (1,-1) (Kellard, 2002). The risk premium can be ignored in the test equation because it is considered to be stationary in theory. The cointegrating equation can be specified as:

$$S_t = \alpha + \beta_1 F_{t-1} + u_t \qquad (2)$$

where $u_t = \beta_2 \pi_{t-1} + v_t$ and must be integrated to order zero.

The unbiasedness hypothesis requires that $\alpha = 0$ (assuming the risk premium has a zero mean), $\beta_1 = 1$ and u_t should be serially uncorrelated. Rejection of the null hypothesis can therefore be explained by one of the following:

(1)   the futures market is inefficient,

(2)   a non-zero risk premium exists,

(3)   both (1) and (2) are true.

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The unbiasedness hypothesis implies that the current futures price of a commodity should equal the future spot price for a given commodity at contract maturity (McKenzie *et al*, 2002). It is only when futures markets are unbiased and efficient that minimum variance hedge ratios are optimal (Benninga *et al*, 1984). The optimality of these hedge ratios is important if the practice of futures market hedging is to provide a useful tool for price risk management. Many studies (e.g., Chowdhury, 1991; Krehbiel and Adkins, 1993) have found no evidence of cointegration between spot and futures prices, or have found cointegration but not with the cointegrating vector (1,-1).

Brenner and Kroner (1995) argue that profit maximizing investors will trade up to the point where they are indifferent between buying the commodity in the spot market (and incurring the associated storage costs while benefiting from convenience yields) and investing in risk free bonds and purchasing futures contracts to be settled later at the currently quoted price. This no-arbitrage situation leads to the following:

$$S_t - F_t = Q_{t-1} - R_{t-1} - C_{t-1} + Y_{t-1} + v_t \tag{3}$$

where Q_{t-1} is the marking-to-market feature of futures markets (which goes to zero as the contract approaches maturity), R_{t-1} is the interest rate, C_{t-1} is the storage costs as proportion of the spot price, Y_{t-1} is the convenience yield and v_t is white noise. The marking-to-market component is normally omitted because it is non-stochastic and small (though it may be reflected in any constant term included in the test equation). Most researchers are content to assume that $C_{t-1} - Y_{t-1}$ is stationary, therefore if the spot and futures prices and the interest rate are non-stationary a (simplified) necessary condition for this model is that there exists tri-variate cointegration with the cointegrating vector (1,-1,1). This cointegrating regression is expressed as follows:

$$S_t = \alpha + \beta_1 F_{t-1} + \beta_2 R_{t-1} + w_t \tag{4}$$

The BK hypothesis requires that $\beta_1 = 1$ and $\beta_2 = -1$. By implication $w_t = (C_{t-1} - Y_{t-1}) + v_t$ and are stationary. The interest rate, R, in equation 3 represents the 'risk premium' in the BK

model. Therefore, the BK model can be thought of as a special case of the unbiasedness hypothesis (Chow, 2001). Consequently, testing for market efficiency requires the following to be examined:

1. If the interest rate is stationary, the natural logarithms of the spot and futures prices at any lead or lag must be cointegrated with vector (1, -1) before the market efficient hypothesis can be accepted.

2. If the interest rate is nonstationary then the natural logarithms of the spot price, futures price, and the interest rate should form a tri-variate cointegrated system with the cointegrating vector (1,-1,1).

As Kellard (2002) points out it is impossible from a theoretical perspective for two variables that are found to be cointegrated with each other to be simultaneously cointegrated with a third variable. Therefore, if the spot and futures prices are cointegrated we would not expect to find cointegration between the spot price, futures price and the interest rate. However, given the empirical irregularities found by Kellard (2002) we will perform cointegration tests on both equations 2 and 4 in section 4.

3. Data

In this paper, the spot price, S_t, is the weekly cash price for the UK in the termination week of the futures contract as published by Department of Environment, Food and Rural Affairs (DEFRA). The futures prices were obtained from wheat futures contracts traded in LIFFE. The frequency of each series corresponds to the number of delivery months. UK wheat futures contracts have six delivery months per year (January, March, May, July, September and November). The futures prices, F_{t-1}, are those observed two calendar months prior to the date of contract maturity. The cointegration regressions are given by equation 2 and 4. The interest rate is the Bank of England repo base rate. The British Bankers' Association defines REPO rates as, "*Repurchase agreements (repos) are collateralised lending*

transactions. One party agrees to sell securities (e.g. gilts) to the other against a transfer of funds. At the same time the parties agree to repurchase the same or equivalent securities at a specific price in the future". These observations for each variable cover the period from November 1985 to January 2004 for all variables. The number of observations used in the analysis is 110.

4. Results

The first step in the analysis was to test the logarithm of each time series for the presence of a unit root using the Augmented Dickey-Fuller (ADF) test. The test equations passed residual tests for normality and serial correlation. The ADF test results, presented in Table 1, show that the interest rate, spot price and futures price series are all found to be I(1). Therefore, these test results concur with those of Aulton *et al.* (1997) and with those of Kellard (2002) who tested a similar wheat futures price series (from LIFFE) although over a different time period. ADF tests, not reported here, were also carried out on the first differences of the three time series and the results indicated that the differenced series were I(0).

Table 1.   Unit Root Tests (ADF)

Series	DF	ADF	k	5% Critical value
S_t	-2.397	-2.391	6	-3.45
F_{t-1}	-2.105	-2.185	6	-3.45
R_{t-1}	-1.587	-2.751	6	-3.45

Note: All tests include both a constant term and a time trend; DF is the Dickey-Fuller test statistic (H_0: series contains a unit root); ADF is the augmented Dickey-Fuller test statistic at the lag length that removes serial correlation; and, k is the lag length chosen.

The finding that the interest rate is I(1) suggests that the appropriate cointegrating regression for testing the efficiency of the wheat futures market at LIFFE is given by equation 4. However, given the empirical results obtained by Kellard (2002) and the paradox that he uncovered, one of the aims of this paper is to use both the specifications given by equations 2 and 4 in testing the efficiency of wheat futures market in the UK.

Using the Johansen approach (Johansen, 1988, 1991; Johansen and Juselius, 1990) tests for cointegration were carried out on the specifications represented by equations 2 and 4. The results of the application of Johansen's reduced rank regression method applied to equation 2 are presented in table 2, while the results for equation 4 are given in Table 4. The order of the VAR was predetermined by likelihood ratio (LR) tests that determined the validity of the restrictions imposed by successive reductions in lag length. These tests were carried out in conjunction with Lagrange Multiplier tests for autocorrelation. The tests suggested that the appropriate specification should be either VAR(1) or VAR(2) in all cases, so the results for both VAR lag lengths are given. The maximal eigenvalue and trace test statistics presented in Table 2 indicate that the null hypothesis of no-cointegration is rejected (in the case of $\{S_t, F_{t-1}\}$ as specified in equation 2). In each case the null hypothesis of no cointegration (rank = 0) is rejected at the 1% level of significance. The finding of rank ≤ 1 cannot be rejected and this indicates that one cointegrating relationship is found in the case of the specification given by equation 2.

Table 2. Test of Cointegration Rank: (S_t, F_{t-k})

Hypothesis	Trace	Max. Eigen	Lag Length	Comment
H_0: r = 0 H_1: r = 1	94.24 (0.00)**	90.34 (0.00)**	1	Rank
H_0: r = 0 H_1: r = 1	42.29 (0.00)**	38.69 (0.00)**	2	= 1
H_0: r ≤1	3.90 (0.440)	3.90 (0.439)	1	Reject non-
H_0: r ≤1	3.60 (0.486)	3.60 (0.485)	2	cointegration

Note: Figures in parentheses are P-values.

The separate and joint restrictions of $\alpha = 0$ and $\beta_1 = 1$ imposed on the cointegrating regression given in equations 2 are tested using Wald tests. The results are presented in Table 3. The test results in Table 3 indicate that the separate restrictions of $\alpha = 0$ and $\beta_1 = 1$ imposed on equation 2 hold, while the joint restriction of $\alpha = 0$ and $\beta_1 = 1$ does not hold.

Table 3. Wald Tests of Parameter Restrictions ($S_t = \alpha + \beta_1 F_{t-1} + u_t$)

H_0: $\alpha = 0$	H_0: $\beta_1 = 1$	H_0: $\alpha = 0$ and $\beta_1 = 1$
1.64 (0.20)	2.37 (0.12)	27.43 (0.00)**

The maximal eigenvalue and trace test statistics presented in Table 4 indicate that the null hypothesis of no-cointegration (rank = 0) is rejected at the 1% level of significance (in the case of {S_t, F_{t-1}, R_{t-1}} as specified in equation 4). The finding of rank ≤ 1 cannot be rejected and this indicates that one cointegrating relationship is found in the case of the specification given by equation 4.

Table 4. Test of Cointegration Rank: (S_t, F_{t-1}, R_{t-1})

Hypothesis	Trace	Max. Eigen	Lag Length	Comment
H_0: r = 0 H_1: r = 1	105.1 (0.00)**	94.8 (0.00)**	1	Rank = 1
H_0: r = 0 H_1: r = 1	49.7 (0.00)**	40.9 (0.00)**	2	
H_0: r ≤1 H_1: r = 2	10.28 (0.62)	7.87 (0.57)	1	Reject non- cointegration
H_0: r ≤1 H_1: r = 2	8.76 (0.76)	6.08 (0.78)	2	

Note: Figures in parentheses are P-values.

The separate and joint restrictions of $\alpha = 0$, $\beta_1 = 1$ and $\beta_2 = -1$ imposed on the cointegrating regression given in equations 4 were tested using Wald tests and the results are presented in Table 5.

Table 5. Wald Tests of Parameter Restrictions ($S_t = \alpha + \beta_1 F_{t-1} + \beta_2 R_{t-1} + w_t$)

H_0: $\beta_2 = -1$	H_0: $\beta_2 = 0$	H_0: $\alpha = 0$, $\beta_1 =$ 1 and $\beta_2 = -1$	H_0: $\alpha = 0$, $\beta_1 =$ 1 and $\beta_2 =0$	H_0: $\beta_1 = 1$ and $\beta_2 = 0$
3521.84 (0.00)**	0.0094 (0.92)	131286.0 (0.00)**	27.19 (0.00)**	2.35 (0.31)

The result of the LR test of the joint restrictions of $\alpha = 0$, $\beta_1 = 1$ and $\beta_2 = -1$ imposed on the cointegrating regression given in equations 4 is presented in column 3 of Table 5. In this case the null hypothesis is firmly rejected. A test of the separate restriction, $\beta_2 = -1$, showed that this was also rejected, while a test of the restriction, $\beta_2 = 0$, was could not be rejected. Therefore although cointegration was found among the variables in the specification given by equation 4 the parameter associated with the interest rate variable was not significantly different from zero. This means that the BK hypothesis must be rejected.

5.   Conclusions

The analysis in this paper employs cointegration methodology to test both the 'unbiasedness hypothesis' and the 'BK hypothesis' to investigate long-run market efficiency in the UK wheat futures. The analysis indicated that the spot and lagged futures prices are cointegrated with the vector (1,-1), while the spot price, lagged futures price and lagged interest rate are cointegrated but not with the cointegrating vector (1,-1,1). The finding of cointegration means that one of the necessary conditions for market efficiency is met and it suggests that the futures market provides useful information about future spot prices for wheat.

The results in this paper do not lead to the same paradox uncovered by Kellard (2002). The non-rejection of cointegration between the spot and lagged futures prices with the vector (1,-1) implies rejection of cointegration among the spot price, lagged futures price and lagged interest rate with the cointegrating vector (1,-1,1). In this paper the former was accepted and the latter was rejected.

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