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Price Hikes in US Agricultural Commodity Futures Markets: An Empirical Efficiency Test

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Abstract

This paper evaluates how efficient US futures prices have predicted future spot prices since 2006. It uses cointegration and causality methods to assess the efficiency of US commodity futures markets. The cointegration between the spot and futures price is a necessary condition for our definition of market efficiency. It ensures that there exists a long-run equilibrium relationship between the two prices (Ali and Gupta 2011). Causality assists in examining the existence of lead or lag relationships between futures and spot prices in order to make inferences on the directions (unidirectional or bidirectional) of information flow.

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Introduction

Agricultural futures markets primarily function as a mechanism for discovering prices and managing market risks associated with price variability and stock holding. Holding commodity over time entails risk, and as a reward for that risk, the future spot price must be higher than the current futures price. In general, market participants, including farmers, will hold stocks if futures prices are lower than the expected futures spot prices, net storage cost or marginal convenience yield. For markets to be efficient, we expect spot and futures prices to move together over time to avoid arbitrage opportunities. To perform the risk-transfer and informative or price discovery roles efficiently, we expect futures markets to meet the basic hypothesis of market efficiency[1] – i.e. futures price must be an unbiased predictor of spot price. However, since 2006, the volume of contracts traded on US futures markets has increased dramatically amidst increased price spikes and volatilities. As prices have become more volatile and convergence less predictable, many believe the US futures markets have lost their efficiency of price discovery and risk management functions and may have contributed to recent price spikes and volatility (Stoll and Robert Whaley 2010; US Senate 2009).

Although price spikes and volatility in US agricultural commodities have attracted the attention of the media, studies on the efficiency, causal relationships of recent spikes, and volatility in both spot and futures prices of the US commodity futures markets are rare. Studies on the convergence or the lack thereof between spot and futures prices failed to evaluate causal factors (Irwin et al. 2007). Other studies on recent price spikes focused on regulatory requirements, index investments, and excess speculation. This paper evaluates how efficient US futures prices have predicted future spot prices since 2006. It uses cointegration and causality methods to assess the efficiency of US commodity futures markets. The cointegration between the spot and futures price is a necessary condition for our definition of market efficiency. It ensures that there exists a long-run equilibrium relationship between the two prices (Ali and Gupta 2011). Causality assists in examining the existence of lead or lag relationships between futures and spot prices in order to make inferences on the directions (unidirectional or bidirectional) of information flow.

Data

Data used consists of spot prices and daily closing prices of futures contracts of selected twelve (12) agricultural commodities reported in the Commitments of Traders (COT) reports for 2006-2011. The commodities are CBOT corn, soybeans, wheat, soybean oil, KCBOT wheat, CSCE cotton, coffee C, sugar, cocoa, CME live cattle, lean hogs, and feeder cattle.

Methodology

An efficient agricultural commodity market is one in which the spot market "fully reflects" the available information (Fama 1970); i.e. an efficient futures market should send price signals to the spot market immediately to eliminate supernormal profit from arbitraging on price differences or at maturity, the future prices become equivalent to spot prices except for some transaction costs. With cost-of-carry (stochastic convenient yield) and no-arbitrage profit expectation, the efficiency in US agricultural futures markets can be represented as:

$$(1) \qquad F_{t,t-k} = S_{t,t-k} + d_t$$

where d_t is the cost-of-carry or stochastic convenience yield, $F_{t,t-k}$ is the futures price at time t for delivery at time t-k, and S_{t-k} is the expected spot price at maturity of the contract, i.e. time t-k. If the cost-of-carry is stationary or zero, th -arbitrage model implies that the futures price is cointegrated with the spot price. Two critical criteria must be met to ensure long-term efficiency of US commodity futures markets – i.e. S and F must be integrated (stationary) to the same order and they must also be cointegrated, otherwise S and F will tend to drift apart over time.

Cointegration Test

The no-arbitrage profit condition of market efficiency suggests that spot and futures prices will only be co-integrated if the cost-of-carry is stationary. We tested for stationarity using "Augmented Dickey-Fuller Test" (Dickey 1984; Dickey and Fuller 1979, 1981). This involves estimating lagged values of ΔX until autocorrelation is eliminated. The test is based on equation:

$$(2) \qquad \Delta X_t = \mu + \delta_t + \rho X_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta X_{t-j} + \varepsilon_t$$

where X_t and X_{t-1} are the present and the immediate past values of a variable, respectively; and μ_t is a stationary error term. The null hypothesis $\rho = 0$ can be tested using a t-statistic. j is the minimum lag length of the augmentation term, necessary to reduce the residuals to white noise.

The second critical condition that must be satisfied to ensure long-term market efficiency in US commodity futures markets is cointegration – i.e. we investigated whether the final settlement spot prices and the futures prices are cointegration. Generally, the presence of cointegration ensures long term relationship of spot and futures prices and the absence of cointegration shows that spot and futures prices drift apart without bound or the futures price provides little information about the movement of the spot price.

Our approach is based on the vector auto-regression (VAR) framework developed by Johansen (Johansen 1988; Johansen and Juselius 1990). Johansen's cointegration tests have been used to assess the long-run relationship among spot and futures prices, using maximum likelihood technique. The Johansen's cointegration test, assuming an n-dimensional vector X_t with integration of an order I(1), estimates a vector autoregressive models. Johansen and Juselius (1990) further improved the model by incorporating an error correction as:

$$(3) \qquad X_t = c + \sum_{i=1}^{k} \prod_i X_{t-1} + \varepsilon_t$$

$$(4) \qquad X_t = \mu + \sum_{i=1}^{\mu-1} r_i \, \Delta_i X_{t-1} + \prod_i X_{t-1} + \varepsilon_t$$

where X_t is an n x 1 vector of the I(1) variables representing spot (S_t) and futures (F_{t-n}) prices, respectively, μ is a deterministic component which may include a linear trend term, an intercept term, or both, Δ denotes the first difference operator, $\prod_i$ is an n x r matrix of parameters indicating α and β, c is a vector of constants, k is lag length based on the Hannan-Quinn criterion, and ε_t is error term, indicating how many linear combinations of X_t are stationary.

The cointegration model asserts that if the coefficient matrix ∏ has reduced rank r < k, then co-integrating relationship can be determined by examining the rank of the coefficient matrix ∏, which is based on the number of co-integrating vectors. The e rank of ∏ thus defines the number of co-integrating vectors. For the two variables (S_t and $F_{0,t}$) in our study, the maximum rank of ∏ will be 2, indicating that S_t and $F_{0,t}$ are jointly stationary. A rank of one (1) will indicate a single cointegration and a zero (0) rank will indicate lack of cointegration between S_t and $F_{0,t}$. Johansen suggests the trace and maximum eigenvalue likelihood tests to determine the rank of ∏. These are presented in equations (5) and (6) respectively:

$$(5) \qquad J_{trace} = -T\sum_{i=r+1}^{n}\ln\left(1-\hat{\lambda}_i\right)$$

$$(6) \qquad J_{max} = -T\ln\left(1-\hat{\lambda}_{r+1}\right)$$

where T is the sample size and $\hat{\lambda}$ is the i:th largest canonical correlation. Asymptotic critical values have been provided by Johansen and Juselius (1990) as test statistics.

Causality Test

We conducted linear Granger causality tests in order to analyze the dynamic relationship between the spot and futures prices. These tests allow us to make some inferences about the causal relations and direction of information flows between spot and futures markets of the 12 agricultural commodities – i.e. to examine whether changes in the price of futures contracts lead changes in spot prices, whether changes in spot prices lead changes in futures prices, or both. Formally, the Granger causality test determines whether the past values of the first valuable contain additional information on the current value of the second variable that is not contained in the past values of the later. If so, then the first variable is said to Granger-cause the second variable. We defined the spot price of a commodity as:

$$(7) \qquad RS_t = InS_t - InS_{t}\text{-}1$$

where S_t is the price in the spot market at time (day) *t*, and the futures return is defined as:

$$(8) \qquad RF_t = InF_t - InF_{t-1}$$

where F_t is the futures price of the nearby contract at time *t*. We used the first difference I(1) of the daily returns of spot (RS_t) and futures (RF_t) for our Granger causality test because the results of equation (1) on the logs of spot and futures prices of each of the twelve commodities are found to be I(1) or first difference stationary. More specifically, our Granger causality test involved analyzing the relationship between RS_t and p lagged values of RS_t and RF_t by estimating the regression models:

$$(9) \qquad RS_t = a_0 + \sum_{k=1}^{p} a_{1k} RS_{t-k} + \sum_{k=1}^{p} a_{2k} RF_{t-k} + e_t$$

$$(10) \qquad RF_t = a_0 + \sum_{k=1}^{p} a_{1k} RF_{t-k} + \sum_{k=1}^{p} a_{2k} RS_{t-k} + e_t$$

F-test is used to test whether RF_t does not Granger-cause RS_t by examine the null hypothesis that the lagged coefficients of RF_t are equal to zero. A similar F-test was used to test the opposite effect – i.e. whether RS_t does not Granger-cause RF_t. The critical aspect here is the choice of lags (k) in both equations (9) and (10). Insufficient lags could yield incorrect test statistics, while too many lags may reduce the power of the test. Hence the lag structure suggested by Akaike Information Criterion (AIC) within each commodity is used for testing causality.

Results

Integration (Stationarity) Results

All the results (not presented) of the Dickey and Fuller (ADF) and Phillips and Perron (PP) unit root tests for the twelve selected commodities showed that both the spot and futures prices are not stationary but become stationary at the first difference. The results are characterized as I(1) or first difference stationary. This satisfies the first criterion of our market efficiency definition.

Cointegration Results

The cointegration results test the second condition of our definition of market efficiency. Table 1 presents the cointegration results from applying equations (5) and (6) to the price series of the twelve agricultural commodities. The results of the Johansen λ_{trace} and λ_{max} indicate that the null hypothesis of non- cointegration (r = 0) is rejected at the 5 percent significant level for all the 12 commodities. The only departure from these results is Coffee traded on ICE where the results show no- cointegration. These results show that there are cointegrations between the spot and futures prices for all the twelve agricultural commodities in our study. The existence of cointegration satisfies our second condition of long-term market efficiency and indicates that the U.S. agricultural futures prices efficiently predict spot prices or the futures prices provide enough information about the movement of the spot prices.

Table 1. Johansen's Cointegration Results for 12 Agricultural Commodities: 2006-2011

Commodities		**Trace Statistics**		**Maxeigen Statistics**		**Co/Non- cointegration**
	r	λ_{trace}	*p-value*	λ_{max}	*p-value*	
CBT Corn	H_0: r = 0	13.8268***	0.0878	12.1373	0.1056	cointegrated
	H_0: r ≤ 1	1.6895	0.1937	1.6895	0.1937	
CBT Soybean Oil	H_0: r = 0	12.9273	0.1175	7.8956	0.3894	cointegrated
	H_0: r ≤ 1	5.0316**	0.0249	5.0316**	0.0249	
CBT Soybean	H_0: r = 0	36.4335*	0.0000	33.4153*	0.0000	cointegrated
	H_0: r ≤ 1	3.0183***	0.0823	3.0183**	0.0823	
CBT Wheat	H_0: r = 0	16.3515**	0.0371	10.3043	0.1927	cointegrated
	H_0: r ≤ 1	6.0471	0.0139	6.0471**	0.0139	
CME Feeder Cattle	H_0: r = 0	164.1221*	0.0001	163.9620*	0.0001	cointegrated
	H_0: r ≤ 1	0.1601	0.6891	0.1601	0.6891	
CME Lean Hog	H_0: r = 0	105.6599*	0.0001	100.7869*	0.0000	cointegrated
	H_0: r ≤ 1	4.8729	0.0273	4.8729	0.0273	
CME Live Cattle	H_0: r = 0	108.3159*	0.0001	106.7413*	0.0001	cointegrated
	H_0: r ≤ 1	1.5746	0.2095	1.5746	0.2095	
CSCE Cocoa	H_0: r = 0	64.1010*	0.0000	60.4994*	0.0000	cointegrated
	H_0: r ≤ 1	3.6015	0.0577	3.6016***	0.0577	
CSCE Coffee	H_0: r = 0	7.6394	0.5047	5.3792	0.6934	Not cointegrated
	H_0: r ≤ 1	2.2601	0.1327	2.2602	0.1327	
CSCE Cotton	H_0: r = 0	99.5270*	0.0001	97.9951*	0.0000	cointegrated
	H_0: r ≤ 1	1.5319	0.2158	1.5319	0.2158	
CSCE Sugar	H_0: r = 0	26.6062*	0.0007	25.1778*	0.0007	cointegrated
	H_0: r ≤ 1	1.4284	0.2320	1.4284	0.2320	
KCBT Wheat	H_0: r = 0	15.7601**	0.0456	11.2273	0.1432	cointegrated
	H_0: r ≤ 1	4.5328	0.0332	4.5325**	0.0332	

Causality Results

The Granger causality test result is reported in Table 2. The upper and lower rows of the F-statistic column reports the null hypotheses that futures price does not Granger-cause spot price, and spot price does not Granger-cause futures price respectively. Generally, the null hypothesis that the futures markets prices do not Granger-cause the prices in spot markets is uniformly rejected at the 1 percent significance level for all commodities. Only in CSCE cotton and KCBT wheat do spot prices Granger-cause futures prices.

Table 2. Granger Causality Test Results for 12 Agricultural Commodities: 2006-2011

Commodities	Hypothesis	F-statistic	Prob.	Direction	Relation
CBOT Corn	S/→ F	6.7997*	0.0006	Bi-directional	F ↔ S
	F/→ S	4.9011*	0.0000		
CBOT Soy Oil	S/→ F	4.7170*	0.0122	Bi-directional	F ↔ S
	F/→ S	3.2169**	0.0009		
CBOT Soybean	S/→ F	0.8892	0.4696	Unidirectional	F →S
	F/→ S	11.6667*	0.0000		
CBOT Wheat	S/→ F	3.2154**	0.0122	Bi-directional	S ↔ F
	F/→ S	7.5143*	0.0000		
CME Feeder Cattle	S/→ F	49.9006*	0.0021	Bi-directional	F↔ S
	F/→ S	4.2364*	0.0021		
CME Lean Hog	S/→ F	35.9276*	0.1214	Unidirectional	F → S
	F/→ S	1.8252	0.0000		
CME Live Cattle	S/→ F	2.4327**	0.0456	Bi-directional	S↔ F
	F/→ S	39.9023*	0.0000		
CSCE Cocoa	S/→ F	2.2027***	0.0665	Bi-directional	S↔ F
	F/→ S	813.6660*	0.0000		
CSCE Coffee	S/→ F	2.3410***	0.0531	Bi-directional	S ↔ F
	F/→ S	38.8080*	0.0000		
CSCE Cotton	S/→ F	9.2136*	0.0000	Unidirectional	S → F
	F/→ S	1.6677	0.1549		
CSCE Sugar	S/→ F	12.0757*	0.0000	Bi-directional	S ↔ F
	F/→ S	71.2041*	0.0000		
KCBT Wheat	S/→ F	0.3169	0.0000	Unidirectional	S → F
	F/→ S	7.8976*	0.8668		

Table 3 is a two-by-three matrix of the cointegration and causality test results. Generally, commodities with cointegration and uni-directional relationship of futures market prices leading the spot market prices (F → S) have better ability to discover prices than those with cointegration and bi-directional relationship. Table 3 shows that future prices Granger cause spot prices (F → S) in 2 commodities (CBOT soybean and CME lean hogs). The implication is that futures market prices have stronger ability to discover spot prices or spot market prices are influenced by the futures market prices only in these two commodities. Table 3 also reports bidirectional causality relationship (F ↔ S) results 8 commodities in 2006-2011. However, examination of the F-statistics for all bidirectional relations for the twelve commodities indicate strong evidence that futures market prices dominate or lead spot markets prices. These results suggest that futures markets dominate spot markets or, equivalently, that the spot prices for these commodities are discovered in the futures markets.

Table 3. Cointegration and Granger Causality Tests Summary

Cointegration	Unidirectional (S → F)*	Unidirectional (F → S)	Bi-directional (F ↔ S)
		Period: 2006 - 2011	
Non-Cointegration	None	I commodity CSCE Coffee	None
Cointegration	2 commodities KCBT Wheat CSCE Cotton	2 commodities CBOT Soybean CME Lean hogs	8 commodities CBOT Wheat CBOT Corn CBOT Soy oil CME Live cattle CME Feeder cattle CSCE Cocoa CSCE Sugar CSCE Coffee

Source: Compiled from Tables 1 and 2. *F = futures prices; S = spot prices

Conclusion

The results of the Johansen's cointegration tests have shown that the spot and futures markets for the 12 agricultural commodities are cointegration. This suggests that the markets are efficient and the agriculture commodity futures exchanges (CBOT, KCBT, CME, and ICE) provide efficient hedge against price risks for agricultural commodities. The Granger causality test results show bi-directional flow of information in majority of the commodities during period. This shows both the spot and future markets are equally responsible for the price discovery process. However, examination of the F-statistics indicates a strong flow of information from the futures markets to spot markets than the reverse. The unidirectional causal relationships exhibited by wheat, soybean, lean hogs and cocoa, imply that the futures markets help discover prices in the spot markets and that the markets are efficient. The results meet our three criteria of market efficiency and suggest that there may be no need to change current futures market regulations.

References

Ali, J., and K.B. Gupta, 2011. "Efficiency in Agricultural Commodity Futures Markets in India: Evidence from Cointegration and Causality Tests." *Agricultural Finance Review* 71 (2):162–178.

Dickey, D. and W. Fuller.1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74:427-431.

Dickey, D. and W. Fuller. 1981. "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root." *Econometrica* 49:1057-1072.

Dickey, D.A., 1984. "Powers of unit root tests." Proceedings of the American Statistical Association.

Fama, E. F. 1970. "Efficient Capital Markets: A Review of Theory and Empirical Work." *The Journal of Finance* 25: 387-417.

Irwin, S.H., P. Garcia, and D.L. Good. 2007. "The performance of Chicago Board of Trade Corn, Soybean, and Wheat Futures Contracts after Recent Changes in Speculative Limits." University of Illinois Working Paper.

Johansen, S., 1988. "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control* 12(2–3): 231–254.

Johansen, S., and K. Juselius. 1990. "Maximum Likelihood Estimation and Inference on Cointegration, with Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics* 52:169-210

Phillips, P.C.B. and P. Perron. 1988. "Testing for Unit Roots in Time Series Regression." *Biometrika* 75:335-346.

United States Senate. 2009. "Excessive Speculation in the Wheat Market, Hearing and Testimony, Permanent Subcommittee on Investigations." United States Senate, July 21, 2009.