PRICE RELATIONS AMONG HOG, CORN, AND SOYBEAN MEAL FUTURES

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This paper examines the relations among hog, corn, and soybean meal futures price series using the Perron (1997) unit root test and autoregressive multivariate cointegration models. Accounting for the significant seasonal factors and time trends, we find the three series are cointegrated with one single cointegrating vector, whose coefficients are comparable to the ratios used by the United States Department of Agriculture (USDA). Ex-post trading simulations that utilize the cointegration results generate significant profits, suggesting that market expectations may not fully incorporate the mean-reverting tendencies as indicated by the cointegration relations, and that inefficiency exists in these three commodity futures markets. Results from our ex-ante trading simulations that employ the USDA ratios also provide some evidence in this regard. © 2005 Wiley Periodicals, Inc. Jrl Fut Mark 25:491–514, 2005

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INTRODUCTION

There has been a plethora of finance studies on the interaction among commodity futures prices that are related to each other through a production process. Interest in these related futures markets has increased considerably following the large reduction in transaction costs and technological advancement in trading systems and communications that make futures transactions inexpensive and convenient to hedgers and speculators.

Early studies have focused on examining hedging strategies using commodity futures contracts and their impact on producer's profit and risks. Leuthold and Mokler (1980), Shafer, Griffin, and Johnson (1978), and Schroeder and Hayenga (1988) investigate the results of three-way hedges that buy corn and feeder cattle futures and sell live cattle futures. Kenyon and Shapiro (1980) compute broiler feeding margins using iced broiler, corn and soybean futures prices and examine the results of hedging strategy implemented when the margins exceed a threshold. Kenyon and Clay (1987) document increased average profits and reduced return variance by employing selective profit margin hedging with hog, corn, and soybean futures.

Another group of studies explores the information flow and market efficiency in these related futures markets. Schwarz and Szakmary (1994), Adrangi, Chatrath, and Raffiee (2002), and Locke and Sarajoti (2002) analyze the price behavior, price discovery, and information flow among futures prices of crude oil, gasoline, and heating oil, the crack spread constituents. Girma and Mougoue (2002) investigate the relation between petroleum futures spread variability, trading volume, and open interest and find evidence of market inefficiency. Johnson et al. (1991) use a profit margin trading rule to examine the market efficiency of the soybean, soybean oil, and soybean meal futures (i.e., the crush spread) and find that nearby futures price spreads are more efficient than distant ones. McKenzie and Holt (2002) study the market efficiency of live cattle, hog, corn, and soybean meal futures markets and suggest that the four futures markets exhibit pricing efficiency in the long run along with some short-run pricing biases.

A third group of studies examines the relations among the futures price series and tests whether profits can be obtained by executing trading strategies based on these relations. Girma and Paulson (1999) find that crude oil, gasoline, and heating oil futures prices are cointegrated and trading strategies based on three popular spreads—3:2:1, 1:1:0, and 1:0:1

crude, gasoline, and heating oil spreads produce significant profits. Simon (1999) and Emery and Liu (2002) examine the crush spread and spark spread (electricity and natural gas futures) and find similar results.

Our work is related to this third group of studies and focuses on the price relations among hog, corn, and soybean meal futures. Corn and soybean meal are the major food for hogs. For the majority of hog producers who do not grow their own feeds, the prices of the three commodities are the most important determinants of their gross profit margin and are also beyond their control. Thus hog farmers are subject to substantial price risk exposure. A good example is the unexpected plunge of this gross profit margin due to excessive hog slaughter capacity and relatively strong corn and soybean meal prices in December 1998 that caused many hog producers to cut back production or liquidate operations altogether. To address these price risks, hog producers have long been interested in using common hedging tools like futures, options, or options on futures. The minimum contract sizes of these financial derivatives, however, have limited the use of them to large producers. The recent introduction of the Livestock Gross Margin (LGM), a pilot futures-based revenue insurance plan offered to Iowa swine producers by the U.S. Department of Agriculture (2001), was aimed to address this issue. It provides coverage for the difference between the actual gross margin and the gross margin guarantee,[1] and can be tailored to any scale of production. In essence, the policy is equivalent to taking positions in the three commodity futures markets: short hog and long corn and soybean meal futures. Such a hedging strategy is similar to those used by oil refiners who short gasoline and heating oil and long crude oil futures, soybean processors who short soybean oil and soybean meal and long soybean futures, and electric utilities who short electricity and long natural gas futures. The last three have been known as the crack spread, crush spread, and spark spread. Along this line, we name the hog-corn-meal feeding spread simply the "hog spread."

The hog spread is not new. It has been available since the live hog futures contract began trading at the CME in the 1960s.[2] Hog producers trade the spread as a way to manage operating risk and protect themselves from the wild swings in profit margins while speculators use it to

[1]The actual gross margin is calculated as the actual lean hog price less feed costs computed based on Chicago Board of Trade corn and soybean meal futures settlement prices. The gross margin guarantee is equal to Chicago Mercantile Exchange (CME) lean hog futures price less feed costs based on Chicago Board of Trade (CBOT) corn and soybean meal futures prices.

[2]Corn and soybean meal futures contract had been traded at CBOT before the hog futures was initiated.

make profits when the prices fluctuate beyond the boundaries determined by the feeding process. Despite extensive use of the spread, a review of the literature only find two related studies.[3] Kenyon and Clay (1987) examine the effects of hedging strategies on hog producer's profit level and profit variation in the spot markets, and McKenzie and Holt (2002) analyze the market efficiency of cattle, hog, corn, and soybean meal futures contracts separately. Our paper, in contrast, studies the linkage among the three commodity futures markets.

Commodity futures markets are fundamentally different from financial futures and financial assets markets in that the carrying costs can be extremely high, and that short sales of the underlying commodities are usually impossible. A cash-and-carry strategy cannot be implemented when temporary excess supply causes the current cash and nearby hog futures prices to be considerably lower than the futures prices for distant delivery, because hogs cannot be stored, and even if they could, the carrying costs would be prohibitive. Similarly, a reverse cash-and-carry strategy is also unfeasible when temporary supply shortages cause current cash and nearby hog futures prices to be much higher than the futures prices for distant delivery, because no one would be willing to give up the convenience yield by lending you the hogs to sell short when supplies are tight and prices are high. As such, the cost of the carry model breaks down, weakening the linkage among futures contracts of different maturity months and resulting in larger variation in term premiums in commodity futures than in financial futures.[4] Such characteristics in commodity futures term structure, defined as the change in futures prices across delivery dates, should theoretically reflect seasonality, trends and mean reversion in commodity futures prices and the hog spread which is composed of three commodity futures prices. In a previous study, Bessembinder et al. (1995) use the relations between price levels and the slope of the futures term structure as an indicator of mean reversion and find large and significant mean reversion in agricultural commodities and crude oil futures markets, smaller but statistically significant mean reversion in metals futures, and weak mean reversion in financial futures markets. In this paper, we examine the mean reversion in the hog, corn, and soybean meal futures markets by using cointegration tests and trading simulations. Because mean reversion has been found in numerous agricultural commodity futures markets, we expect the three futures price series are cointegrated if each of them is integrated of order one.

[3]The LGM is just a more recent example of using the spread.
[4]See Bailey and Chan (1993), Fama and French (1987), and French (1986) for more details.

Cointegration relations among the three futures would indicate the presence of significant mean-reverting tendencies to a long-run equilibrium for the hog spread. These tendencies cannot be taken advantage of if the markets are efficient and futures traders have fully accounted for them. However, if significant trading profits can be generated from these mean-reverting tendencies, then we have evidence that the market expectations as reflected in the futures term structure cannot fully incorporate the mean reversion, and that inefficiency exists in the futures markets.

We begin by looking into the time series properties of the nearby contract settlement price series of three commodities. Allowing for possible breaks in the time series within the sample period, we find that the three futures prices are integrated of order one. Then, using the multivariate cointegration models developed by Johansen (1988, 1991) and accounting for seasonality and time trends, we find that the three price series are cointegrated, suggesting that the hog spread does revert to a long-term equilibrium. In addition, we find only one cointegration vector, whose coefficients are similar to the ratios used by the USDA. Based on these findings, we conduct ex-post and ex-ante trading simulations to investigate the ability of the three futures markets to capture these mean-reverting tendencies. Our ex-post trading simulations that utilize the cointegration relations generate significant profits net of transaction costs, suggesting that these tendencies are not fully incorporated by market expectations, and that a certain level of inefficiency exists in the three commodity futures markets. Our ex-ante trading simulations that employ the USDA ratios also provide further evidence of market inefficiency, although the trading profits generated may not be extremely appealing to futures traders.

The rest of the article is structured as follows. The next section describes the futures data and presents a brief discussion of hog production industry and the gross hog feeding margin. We then examine the time series properties of the three commodity futures prices and apply the multivariate cointegration tests. After that, we conduct trading simulations based on the empirical findings and report the results. The last section contains a brief review of the analysis and offers some concluding remarks.

DATA AND GROSS HOG FEEDING MARGIN

We use the nearby futures prices obtained from the Institute for Financial Markets (www.theifm.org). The hog futures contract is traded at the CME while corn and soybean meal futures contracts are traded at the CBOT. Detailed specifications of the contracts are in Table I. Hog

TABLE I
Hog, Corn and Soybean Meal Futures Contracts*

Futures Contract	*Exchange*	*Contract Size*	*Tick Size*	*Price Quote*	*Contract Months*	*Last Trading Day*
Lean Hog (LH)**	Chicago Mercantile Exchange (CME)	40,000 pounds	1/4 cent/pound	Cents/pound	Feb, Apr, May, Jun, Jul, Aug, Oct, Dec	Tenth business day of the contract month
Corn (C)	Chicago Board of Trade (CBOE)	5,000 bushels	1/4 cent/bushel	Cents and quarter-cents/bushel	Mar, May, Jul, Sep, Dec	The business day prior to the 15th calendar day of the contract month
Soybean Meal (SM)	Chicago Board of Trade (CBOE)	100 tons (2,000 lbs/ton)	10 cents/ton	Dollars and cents/ton	Jan, Mar, May, Jul, Aug, Sep, Oct, Dec	The business day prior to the 15th calendar day of the contract month

*From the Chicago Board of Trade Web site (http://www.cbot.com/) and the Chicago Mercantile Exchange Web site (http://www.cme.com/), October 2002. Ticker symbols are in parentheses.
**Beginning with the February 1997 contract, the Chicago Mercantile Exchange changed the hog contract from live hogs to lean hog carcass.

and corn prices are quoted in cents while soybean meal price in dollars so we adjust accordingly in our study. Our sample ranges from January 2, 1985 to December 31, 2001, a total of 17 years of daily data with 4285 observations. For the hog futures, beginning with the February 1997 contract, the CME changed the hog contract from live hogs to lean hog carcass with the intention to match the contract with the needs of businesses in the meat industry. The lean carcass has averaged 74% of the total body weight of the live hogs so we use a factor of 0.74 to convert between lean hog price and live hog prices.

The hog spread can be calculated from the three price series based on the hog-corn-soybean meal ratios. The ratios, however, vary in the hog production industry. There are three types of hog production enterprises: (1) farrow-to-finish enterprises, which raise hogs from birth to slaughter weight of 250–270 pounds; (2) feeder pig production enterprises, which raise hogs from birth to 20–60 pounds, then sell them to the third type of enterprise for finishing; (3) feeder pig finishing enterprises, which purchase and feed feeder hogs to slaughter weight. Both the first and the third types of enterprises tend to use the hog spread to hedge against declining hog prices and/or rising corn and soybean meal prices.

According to USDA stipulations, the standard projected consumption of corn and soybean meal by a pig with an assumed weight of 260 pounds is 12.95 bushels and 184.89 pounds (or 0.092445 tons),

FIGURE 1
Daily gross hog feeding margin (GHFM), January 2, 1985–December 31, 2001.

respectively, for the first type of enterprises, and 10.41 bushels and 149.46 pounds (or 0.07473 tons), respectively, for the third type of enterprises. We focus on the first type in this paper, since it is by far the most popular among hog producers. The gross hog feeding margin (GHFM) per hog for this type of hog production enterprises is:[5]

$$\begin{aligned} GHFM_t &= \text{Lean hog}_t/100 * 260 * 0.74 - \text{Corn}_t/100 * 12.95 \\ &\quad - \text{Soybean Meal}_t * 184.89/2000 \end{aligned} \tag{1}$$

As Figure 1 shows, the GHFM, calculated using nearby settlement prices, fluctuated wildly from around \$40 to \$70, exhibiting an upward trend over the sample period. There was a steady increase in GHFM from mid-1988 to the first part of 1990 that peaked at \$121.85 per pig on May 22, 1990. On the other side, the GHFM declined precipitously in late 1998 and dipped to a low of −\$0.78 on December 11, 1998 due to low hog prices and relatively high corn and soybean meal prices. Figure 2, which graphs the GHFM by calendar month, shows a strong seasonal pattern for the margin. The margin is almost flat between January and March, then climbs up in April and peaks in May. After that the margin declines and hits bottom in November and December. We will account for the upward trend and seasonal pattern in our modeling and statistical tests in the next section.

[5]Lean hog and corn prices are adjusted from cents to dollars, and a factor of 0.74 is used to convert the lean hog prices to live hog prices.

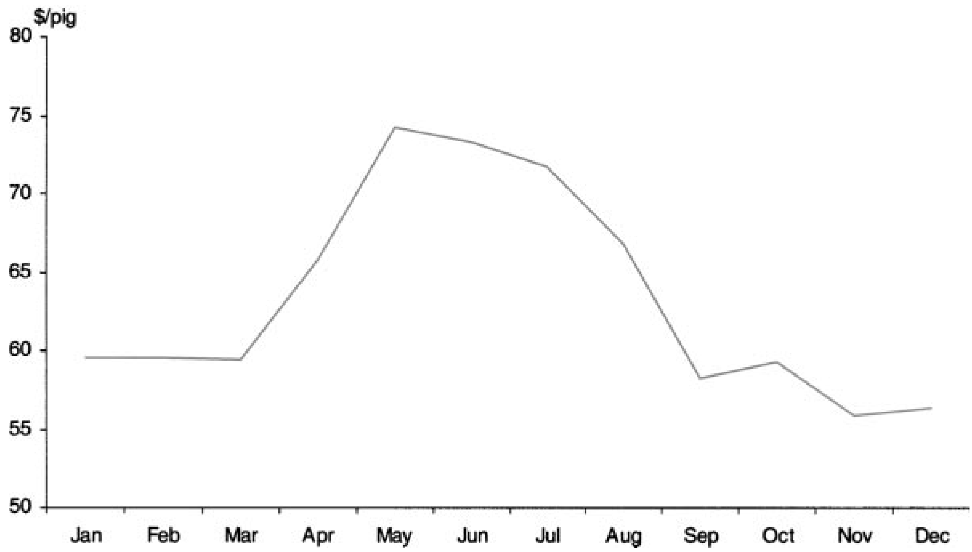

FIGURE 2
Average daily gross hog feeding margin (GHFM) by Month, January 2, 1985–December 31, 2001.

TESTS OF TIME SERIES PROPERTIES

This section examines the time series properties of the hog, corn, and soybean meal futures prices and their relations. We test the stationarity of the time series and investigate the possible cointegration relations among them.

Stationarity Tests

As shown in Figure 1, the general levels of the GHFM after the steady increase between mid-1988 and the first part of 1990 appears to be higher than before the period. Coupled with the fact that the hog futures contract switched from live hog to lean hog in 1997, we need to address the problem that possible breaks within the sample may cause to traditional stationarity tests. Serletis (1992) found that breaks in the intercept and slope of the trend function play an important role in unit root tests and allowance should be made for the possibility of a shift in the intercept and slope of the trend function. In light of this, we employ the Perron (1997) unit root test which allows for a time break correlated with the data. The date of possible change in both the intercept and slope is not fixed a priori and is assumed to occur in a gradual fashion that depends upon the correlation structure of the noise. The optimal

TABLE II
Perron (1997) Unit Root Test Results

Independent Variables	Y_{t-1}	DU_t	DT_t
Hog			
Price level	0.992	−0.639	0.001
	(−4.65)	(−1.08)	(0.99)
1st difference of price	0.025**	0.039	0.001
	(−19.70)	(0.40)	(1.09)
Corn			
Price level	0.993	3.091	−0.001
	(−4.12)	(1.17)	(−3.13)
1st difference of price	0.025**	−2.874	0.001*
	(−21.28)	(−1.62)	(1.98)
Soybean meal			
Price level	0.994	−1.782	0.001
	(−3.93)	(−1.28)	(1.03)
1st difference of price	−0.037**	−1.113	0.001
	(−31.82)	(−1.04)	(1.08)

Note. The Perron (1997) unit root test procedure is conducted by fitting the following model to the price level and first differences of hog, corn, and soybean meal futures. t statistics are in parentheses. The asymptotic critical values for α are −5.57, −5.08, and −4.82 at the 0.01, 0.05, and 0.10 confidence levels respectively.

$$Y_t = \alpha Y_{t-1} + \theta DU_t + \gamma DT_t + \delta D(T_b)_t + \mu + \beta t + \sum_{i=1}^{k} c_i \Delta Y_{t-i} + e_t$$

* and ** denote significance at 0.05 and 0.01 levels, respectively.

break date, T_b, is estimated using a recursive approach to minimize the t statistic for testing $\alpha = 1$ in the following OLS regression:

$$y_t = \mu + \alpha y_{t-1} + \theta DU_t + \delta D(T_b)_t + \gamma DT_t + \beta t + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \qquad (2)$$

where $DU_t = 1(t > T_b)$, $D(T_b)_t = 1(t = T_b + 1)$, and $DT_t = 1(t > T_b)t$ with $1(\bullet)$ being the indicator function. The number of lags, k, is selected using a general to specific recursive procedure to ensure that the coefficient on Δy_{t-k} is significant and that the coefficient on Δy_{t-k-1} is not based on the t statistics.

The results are reported in Table II. All three futures price series can not reject the null hypothesis that a unit root exists, while their first differences reject the null at the 0.01 confidence level, suggesting that they are all integrated of order one, or I(1).[6] On the other hand, the coefficients for DU_t and DT_t are mostly insignificant at the 0.05 level except for the first difference of corn. This suggests that there exist no statistically

[6]Augmented Dickey-Fuller (1979) unit root tests with an intercept, without an intercept, with an intercept and a time trend yield similar results.

significant time breaks within the sample period for the three commodity futures price series.

Multivariate Cointegration Test

Because the hog, corn, and soybean meal futures prices are all I(1) processes and are related through a production process, we test whether one or more linear combinations of them constitute a long-run equilibrium by using the multivariate cointegration test developed in Johansen (1988, 1991) and Johansen and Juselius (1990). This test avoids the problem that the cointegrating relations might change when variables are placed on both sides of the models due to the limited size of the sample.

To distinguish between stationarity by linear combinations and by differencing, we use the error-correction form model derived from the basic three-dimensional vector autoregressive equation:

$$\Delta Y_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \Pi Y_{t-1} + u + \theta D_t + e_t \tag{3}$$

Where $Y_t' = (\text{Hog}_t\ \text{Corn}_t\ \text{Meal}_t)$;
$D_t' = (\text{Jan}_t\ \text{Feb}_t\ \text{Mar}_t\ \text{Apr}_t\ \text{May}_t\ \text{Jun}_t\ \text{Jul}_t\ \text{Sep}_t\ \text{Oct}_t\ \text{Nov}_t\ \text{Dec}_t\ \text{Time\_Trend}_t)$;
$\Pi = \alpha\beta'$, both α and β are $3 \times r$ matrices with r being the cointegration rank;
u is a 3×1 vector of constants; and k is the order of the VAR system.

In this model, we account for the seasonal pattern and upward trend as described in the previous section by including the time trend and monthly dummy variables in D_t. These variables are only included in the short-run dynamics but do not participate in the cointegration space. We chose to leave out the August dummy to avoid dummy trap for two reasons. First, in the hog industry, August is the month when the marketing of previous fall's pigs is ending and early sales of spring hogs are starting. The chances of prices moving up or down at this time are therefore approximately equal. Second, other similar studies usually leave out the December dummy, but here the average December GHFM, as Figure 2 shows, is among the lowest among all months and we want to capture this low in our model.

Johansen and Juselius (1990) show that model (3) can be reformulated as:

$$R_{0t} = \alpha\beta\, R_{1t} + \text{error}, \quad t = 1, 2, \ldots, T \tag{4}$$

in which R_{0t} and R_{1t} are residuals from the regressions:

$$\Delta Y_t = \hat{B}_1 \Delta Z_{t-1} + \hat{B}_2 D_t + R_{0t} \tag{5}$$

and

$$Y_{t-1} = \hat{B}_3 \Delta Z_{t-1} + \hat{B}_4 D_t + R_{1t} \tag{6}$$

The maximum likelihood estimator of β is found by solving:

$$|\lambda S_{11} - S_{10} S_{00}^{-1} S_{01}| = 0 \tag{7}$$

which yields the eigenvalues and corresponding eigenvectors and determines the linear combinations of the cointegrating relations.

The Johansen likelihood ratio test statistic, λ_{Trace}, for the null hypothesis that there are at most r cointegrating vectors is given by:

$$\lambda_{\text{Trace}} = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i) \tag{8}$$

An alternative test statistic, the maximal eigenvalue or λ_{Max}, is also calculated as:

$$\lambda_{\text{Max}} = -T \ln(1 - \hat{\lambda}_r) \tag{9}$$

The test statistics are corrected for small sample bias based on Reimers (1992). The results are presented in Table III. The null hypothesis that $r = 0$, or there is no cointegration relations among the three

TABLE III

Multivariate Cointegration Test Results

Null Hypotheses	*Alternative Hypotheses*	λ_{Trace}	λ_{Trace} *95% Critical Value*	λ_{Max}	λ_{Max} *95% Critical Value*
$r = 0$	$r > 0$	37.45*	24.30	22.81*	17.90
$r \leq 1$	$r > 1$	9.64	12.50	9.79	11.40
$r \leq 2$	$r > 2$	0.88	3.80	0.88	3.80

Based on r = 1, the beta vector is (normalized on hog):

Hog ($/lb.)	Corn ($/bushel)	Soybean Meal ($/ton)
1.00	−0.083	−0.00099

Note. Johansen (1988, 1991) and Johansen and Juselius (1990) multivariate cointegration tests are used to examine the cointegrating relations among hog, corn, and soybean meal futures prices. Two likelihood ratio test statistics, λ_{Trace} and λ_{Max}, are reported along with their 95% critical values. The statistics include a finite sample correction based on Reimers (1992). *denotes significance at 0.05 level.

futures price series, is rejected at the 0.05 confidence level. But the null hypothesis that $r \leq 1$ cannot be rejected by both the trace and max statistics. This suggests that, consistent with the characteristics of the commodity futures markets and term structure, the three agricultural commodity price series are cointegrated in the presence of significant time trends and seasonal factors.[7] The cointegration relations, consistent with the findings of Bessembinder et al. (1995), indicate the presence of mean reversion to a long-run equilibrium for the hog spread which is composed of three agricultural commodities.

In addition, Table III results also show that there is only one stationary linear combination which constitutes a long-run equilibrium of the price relations among the three commodity futures. The elements of this cointegrating vector, normalized on the hog price series, is $(1 - 0.083 - 0.00099)$. Thus, the stationary hog spread suggested by the multivariate cointegration (MC) test results is:

$$Z_{MC} = \text{Hog} - 0.083 \times \text{Corn} - 0.00099 \times \text{Meal} \tag{10}$$

In comparison, the hog spread based on the Gross Hog Feeding Margin in Equation (1), if normalized on the hog price series on a per pound basis, is:

$$Z_{USDA} = \text{Hog} - 0.067 \times \text{Corn} - 0.00048 \times \text{Meal} \tag{11}$$

To the extent that the coefficients in Z_{MC} are reasonably close to those in Z_{USDA}, the difference may be explained by two factors. First, although corn and meal are the main hog feeds, hog farmers use other grains like barley, rye, oats, sorghum, potatoes, sugar beets, etc. It would be ideal to include these other grains' futures prices in the model, but most of them are absent from the futures market. Second, the USDA ratios are derived from the actual feeding process in which hog farmers purchase corn and soybean meal at mostly spot prices. Our data series are futures prices so Z_{MC} coefficients may reflect the virtual feeding process futures traders assume in their models instead of the actual one.

[7]Because we use the nearby contract's price levels in the multivariate cointegration tests, the price changes on rollover days are the second nearby minus the first nearby contract prices. To gauge the impact of these across-contract price changes on the mean reversion as reflected in the cointegration relations, we create unit value index series for the three futures contracts using cumulative daily returns that do not contain the price changes across contracts on rollover days. We then apply the Perron (1997) unit root and multivariate cointegration models to these indexes and find that the three futures series are still cointegrated. This result provides further evidence of mean reversion in the hog spread and inefficiency in the three commodity futures markets.

TABLE IV
Coefficients of Seasonality Variables and Time Trend

Regression: $Z_{MC,t} = a_0 + \sum_{i=1}^{11} a_i D_{i,t} + a_{12}\mathrm{Trend}_t + e_t$

	Coefficient	*t-statistics*
Constant	−0.284**	−3.62
January	−1.725*	−2.27
February	−1.852*	−2.38
March	−1.972**	−2.62
April	2.729**	3.54
May	5.298**	6.99
June	4.153**	5.49
July	3.653**	4.82
September	−2.714**	−3.54
October	−2.385**	−3.18
November	−4.156**	−5.43
December	−3.810**	−5.01
Time Trend	0.002**	3.04
Standard Deviation of Residuals	0.103	
R^2	0.150	
Durbin-Watson statistic	1.856	

Note. $Z_{MC,t} = \mathrm{Hog}_t - 0.083 \times \mathrm{Corn}_t - 0.00099 \times \mathrm{Meal}_t$. It is the stationary hog spread based on the multivariate cointegration test results in Table III. $D_{i,t}$ is the monthly dummy variables for January, February, March, April, May, June, July, September, October, November, and December. * and ** denote significance at 0.05 and 0.01 levels, respectively.

Because the monthly dummy variables and time trend only participate in the short-run dynamics but not the cointegration space, we use the following regression to examine the seasonality and time trend in the hog spread:

$$Z_{MC,t} = a_0 + \sum_{i=1}^{11} a_i D_{i,t} + a_{12}\mathrm{Trend}_t + e_t \tag{12}$$

Table IV reports the regression results. All coefficients are significantly different from zero at least at the 0.05 confidence level, exhibiting strong seasonality and upward trend over the sample period. The positive monthly dummy coefficients start with April, coinciding with the first upward shift in Figure 2, and end with July. The remaining months' coefficients have negative signs. This is consistent with the seasonality in hog production and expected prices. For example, the smaller winter pig crop and larger spring pig crop result in hog supply being lower in summer and higher in the fall. Increased loin grilling in late spring and early summer affects hog demand and strengthens the seasonal pattern. The time

TABLE V
Reversion of Hog Spread to Long-Run Equilibrium

Reversion to long-run equilibrium (e_t is the residual from Table IV):

Regression: $\Delta e_t = \beta_0 + \beta_1 e_{t-1} + \sum_{i=1}^{3} \gamma_i \Delta e_{t-i} + \varepsilon_t$

	Coefficient of e_{t-1}	*τ-statistic*	*Half Life of Shocks*
	−0.0086	−4.31*	80 days
R^2	0.07		
Durbin-Watson statistic	2.000		

Note. The regression model is similar to the augmented Engle-Granger (1987) cointegration test model. * and ** denote significance at the 0.05 and 0.01 confidence levels.

trend is significantly positive, reflecting the fact that corn and soybean prices have been decreasing faster than hog prices due to differential productivity growth in the three industries.

The residual, e_t, from Equation (12) is in essence the stationary hog spread from the multivariate cointegration test results adjusted for the time trend and seasonality. We apply a model similar to the augmented Engle-Granger (1987) cointegration model to examine the reversion of deviation of the hog spread to long-run equilibrium:

$$\Delta e_t = \beta_0 + \beta_1 e_{t-1} + \sum_{i=1}^{3} \gamma_i \Delta e_{t-i} + \varepsilon_t \tag{13}$$

The τ statistic of e_{t-1}, as shown in Panel 1 of Table V, rejects the null hypothesis that cointegration relations do not exist. The half-life of shock from the long-run equilibrium, or $\ln(0.5)/\ln(1 + \beta_1)$, is 80 days. The considerable length of this half-life suggests that although the hog spread reverts to its long-run equilibrium when shocks occur, the speed of such movement is relatively slow.

Error-Correction Models

While the multivariate cointegration test results show that hog, corn, and soybean meal futures prices tend to move together in the long-run, error-correction models examine how each futures price series in the short run adjusts to shocks to the cointegrating relations, Z_{MC}.[8] The models for the error-correction term $Z_{MC,t-1}$ are described by Equations (14), (15), and (16).

[8]See Locke and Sarajoti (2002).

$$\Delta \mathrm{Hog}_t = a_0 + a_1 Z_{\mathrm{MC},t-1} + \sum_{i=1}^{m} \gamma_i \Delta \mathrm{Hog}_{t-i} + \sum_{j=1}^{n} \delta_j \Delta \mathrm{Corn}_{t-j} + \sum_{l=1}^{p} \theta_l \Delta \mathrm{Meal}_{t-l} + \varepsilon_{1t} \tag{14}$$

$$\Delta \mathrm{Corn}_t = b_0 + b_1 Z_{\mathrm{MC},t-1} + \sum_{i=1}^{m} \gamma_i \Delta \mathrm{Hog}_{t-i} + \sum_{j=1}^{n} \delta_j \Delta \mathrm{Corn}_{t-j} + \sum_{l=1}^{p} \theta_l \Delta \mathrm{Meal}_{t-l} + \varepsilon_{2t} \tag{15}$$

$$\Delta \mathrm{Meal}_t = c_0 + c_1 Z_{\mathrm{MC},t-1} + \sum_{i=1}^{m} \gamma_i \Delta \mathrm{Hog}_{t-i} + \sum_{j=1}^{n} \delta_j \Delta \mathrm{Corn}_{t-j} + \sum_{l=1}^{p} \theta_l \Delta \mathrm{Meal}_{t-l} + \varepsilon_{3t} \tag{16}$$

Table VI presents the results. We choose the first-order error-correction model with $m = n = p = 1$ and the Durbin-Watson statistics suggest serial correlation is not present. The coefficients of the error-correction term $Z_{\mathrm{MC},t-1}$ have the expected signs, i.e., negative for hog and

TABLE VI

Results of Error Correction Models

	ΔHog_t		$\Delta Corn_t$		$\Delta Meal_t$	
	Coefficient	t	*Coefficient*	t	*Coefficient*	t
Intercept	0.113***	3.19	−0.086	−0.67	−0.142	−1.54
$Z_{\mathrm{MC},t-1}$	−0.006***	−3.64	0.004	0.64	0.007*	1.80
$\Delta \mathrm{Hog}_{t-1}$	0.017	1.12	−0.110**	−1.99	−0.110***	−2.76
$\Delta \mathrm{Corn}_{t-1}$	−0.002	−0.51	0.149***	8.49	0.010	0.79
ΔSoybean Meal_{t-1}	0.006	0.82	−0.044*	−1.77	0.023	1.30
R^2	0.03		0.02		0.03	
Durbin-Watson statistic	1.998		1.990		2.000	

Note. The error correction term is the spread estimated by multivariate cointegration procedure (MC), or Z_{MC}. The error correction models measure whether and how fast the hog, corn, and soybean mean futures prices adjust to shocks to the cointegrating relations, Z_{MC}. The models are as follows.

$$\Delta \mathrm{Hog}_t = a_0 + a_1 Z_{\mathrm{MC},t-1} + \sum_{i=1}^{m} \gamma_i \Delta \mathrm{Hog}_{t-i} + \sum_{j=1}^{n} \delta_j \Delta \mathrm{Corn}_{t-j} + \sum_{l=1}^{p} \theta_l \Delta \mathrm{Meal}_{t-l} + \varepsilon_{1t}$$

$$\Delta \mathrm{Corn}_t = b_0 + b_1 Z_{\mathrm{MC},t-1} + \sum_{i=1}^{m} \gamma_i \Delta \mathrm{Hog}_{t-i} + \sum_{j=1}^{n} \delta_j \Delta \mathrm{Corn}_{t-j} + \sum_{l=1}^{p} \theta_l \Delta \mathrm{Meal}_{t-l} + \varepsilon_{2t}$$

$$\Delta \mathrm{Meal}_t = c_0 + c_1 Z_{\mathrm{MC},t-1} + \sum_{i=1}^{m} \gamma_i \Delta \mathrm{Hog}_{t-i} + \sum_{j=1}^{n} \delta_j \Delta \mathrm{Corn}_{t-j} + \sum_{l=1}^{p} \theta_l \Delta \mathrm{Meal}_{t-l} + \varepsilon_{3t}$$

Here we choose $m = n = p = 1$ and serial correlation is not detected. *, **, and *** denote significance at 0.10, 0.05, and 0.01 levels, respectively.

positive for corn and soybean meal. Thus when there is a positive transitory shock to Z_{MC}, hog price would decrease and corn and soybean meal prices would increase to force the hog spread to move back toward the equilibrium relations. The opposite would happen when there is a negative shock. On the other hand, t statistics for the coefficients of $Z_{MC,t-1}$ show that the reaction of hog price to the shocks, is statistically significant at the 0.01 level while the reaction of corn and soybean meal prices are at best marginally significant. This asymmetric response may indicate that movements in corn and soybean meal prices have important impact on hog prices but not vice versa, which is consistent with the fact that corn and soybean meal are major hog feeds but they have other uses as well.[9]

TRADING STRATEGIES

The analysis in the preceding section shows that significant mean-reverting tendencies to the long-run equilibrium exist for the hog spread. For market participants, these tendencies should be little surprise because of the break-down of the cost-and-carry model and the resulting large variation in term premiums in agricultural commodity futures markets, which have been well-documented in previous theoretical and empirical studies. If the three commodity futures markets are efficient, traders should expect these tendencies and fully incorporate them into their trading behavior, and no one can take advantage of them to generate meaningful trading profits. However, if these tendencies turn out to be exploitable in our trading simulations, then there is evidence that inefficiency exists in the three futures markets.

The ground rule of our trading strategies is to long (short) the hog spread by buying (selling) lean hog futures and selling (buying) corn and soybean meal futures when the spread is below (above) the long-run equilibrium by a certain level, and then to close the positions by conducting offsetting trades when the spread reverts back to the long-run equilibrium. Similar to Simon (1999) and Emery and Liu (2002), we assume all trades occur at the settlement prices of the nearby contracts. An open position is rolled over on the expiration day by closing the position that day and simultaneously reopening a new position in the second nearby contract.[10]

[9]For instance, corn is an input in alcohol production, and soybean meal is also consumed by turkeys.
[10]In some studies, contracts are rolled over five days prior to the expiration day due to the typically low open interest and high price volatility during the last several trading days. We repeat the ex-post and ex-ante trading simulations with this roll-over rule but cannot find significant differences. Here we present the results for roll-over on the expiration day to be consistent with the way we conduct the unit root and multivariate cointegration tests.

Transaction Costs

We make the following assumptions regarding transactions. Transaction costs are incurred when positions are opened, closed, or rolled over. Consistent with other intercommodity spread studies, we consider two types of transaction costs: slippage costs and brokerage commissions. Slippage is two price ticks per round trip, which translate into 0.5 cents per pound for hog, 0.5 cents per bushel for corn, and 20 cents per ton for soybean meal per round trip based on their respective tick sizes. Brokerage commissions, following Simon (1999), are assumed to be \$15.50 per round trip, which is equivalent to 0.03875 cents per pound for hog, 0.31 cents per bushel for corn, and 15.5 cents per ton for soybean meal. The sum of these two types of transaction costs, therefore, is \$0.0064 $((0.005 + 0.03875) \times 1 + (0.005 + 0.0031) \times 0.083 + (0.20 + 0.155) \times 0.00099)$ for trading the Z_{MC} hog spread on per pound of lean hog basis, and \$0.0061 $((0.005 + 0.03875) \times 1 + (0.005 + 0.0031) \times 0.067 + (0.20 + 0.155) \times 0.00048)$ for trading the Z_{USDA} hog spread.

Ex-post Trading Triggers and Results

The ex-post trading simulations are based on the hog spread estimated by the multivariate cointegration test procedure, so a long (short) position would be to buy (sell) one pound of lean hog, sell (buy) 0.083 bushels of corn, and sell (buy) 0.00099 tons of soybean meal. That is approximately equivalent to trades of 15 lean hog contracts, 10 corn contracts, and 6 soybean meal contracts, considering their respective contract sizes of 40,000 pounds, 5,000 bushels, and 100 tons. Similarly, the ex-ante trading simulations are based on the predetermined hog spread based on the ratios in USDA documents, so a long (short) position would be to buy (sell) one pound of lean hog, sell (buy) 0.067 bushels of corn, and sell (buy) 0.00048 tons of soybean meal. That is approximately equivalent to trades of 10 lean hog contracts, 5 corn contracts, and 2 soybean meal contracts.[11] These ex-ante trades are conducted based only on information available at the time the positions are taken: futures prices of hog, corn, and soybean meal, as well as the USDA ratios. Our simulation results are reported on a basis of one pound of lean hog so they can be easily converted to contract sizes.

Trading is triggered in the ex-post simulations when the deviation from the long-term mean (zero), i.e., e_t in Equation (12), exceeds 0.25, 0.50, 0.75, or 1.00 times its standard deviation, δ_e. The trading rules are as follows. For the long position, go long on day t by buying 1 pound of

[11]Or more closely, 26 lean hog contracts, 14 corn contracts, and five soybean meal contracts.

lean hog, selling 0.083 bushels of corn, and selling 0.00099 tons of soybean meal simultaneously if

$$e_t < -X\delta_e \tag{17}$$

where X is alternately 0.25, 0.50, 0.75, and 1.00, and δ_e is the standard deviation of e_t in the entire sample, or 0.103 as reported on Table IV. Close the position when e_t goes above zero. For the short position, go short on day t by selling 1 pound of lean hog, buying 0.083 bushels of corn, and buying 0.00099 tons of soybean meal simultaneously if

$$e_t > X\delta_e \tag{18}$$

Close the position when e_t falls below 0.

Table VII reports the results for the ex-post trading simulations. The trading triggers and hog spread Z_{MC} are estimated ex-post using all

TABLE VII

Ex-post Trading Simulations Based on Reversion to Long-Run Equilibrium

	Open Position on Day t When e_t is			
	$<-0.25\delta_e$	$<-0.5\delta_e$	$<-0.75\delta_e$	$<-\delta_e$
Panel A: Long Positions				
Number of trades	29	14	13	9
Average duration	66 days	116 days	120 days	131 days
Percent profitable	89.66%	85.71%	84.62%	77.78%
Maximum profit	\$0.156	\$0.183	\$0.201	\$0.234
Minimum profit	−0.134	−0.115	−0.078	−0.069
Average profit	0.040	0.067	0.094	0.106
Standard error	0.013	0.023	0.026	0.040
P value	0.002	0.006	0.002	0.015
	$>0.25\delta_e$	$>0.5\delta_e$	$>0.75\delta_e$	$>\delta_e$
Panel B: Short Positions				
Number of trades	22	16	10	8
Average duration	86 days	105 days	153 days	167 days
Percent profitable	72.73%	81.25%	80.00%	87.50%
Maximum profit	\$0.439	\$0.482	\$0.521	\$0.532
Minimum profit	−0.108	−0.116	−0.076	−0.029
Average profit	0.062	0.093	0.149	0.229
Standard error	0.029	0.037	0.056	0.065
P value	0.022	0.012	0.013	0.005

Note. e_t is the residual from Equation (12) in Table IV. δ_e is the standard deviation of e_t, or 0.103 in our sample. A long (short) position is established by buying (selling) 1 pound of lean hog and selling (buying) 0.083 bushels of corn and 0.00099 tons of soybean meal in the futures market based on the multivariate cointegration results. Trading triggers are 1/4, 1/2, 3/4, and 1 times δ_e respectively. A position is closed by executing the opposite trades when the residual reverts to zero. Trading costs are \$0.0053875 per pound for hog, \$0.0081 per bushel for corn, \$0.355 per ton for soybean meal, and approximately \$0.0064 for trading the Z_{MC} hog spread on a per pound of lean hog basis. *P* values are from the *t* test of the null hypothesis that the average profit is equal to zero.

the data between January 2, 1985 and December 31, 2001. Panel A presents the number of trades, average duration of trades, percentage of trades that are profitable, maximum profit, minimum profit, average profit, standard error of trading profits, and *P* value for the null hypothesis that average profit is equal to zero, for long positions. Results for short positions are in Panel B.

Since the trades for higher trading triggers are actually subsets of the trades for lower triggers, the percentage of trades that are profitable, maximum profits, and average profits increase when trading triggers move further away from the long-run equilibrium. Both long and short trades turn out to be significantly profitable. The majority of trades are profitable with the profits generally skewed to the positive side based on the levels of maximum and minimum profits. The average profits, net of slippage costs, and brokerage commission, are significantly positive at least at the 0.05 level, and are significantly higher than the transaction costs. For example, the lowest average profit of \$0.040 (long positions, trigger $e_t < -0.25\delta_e$) is more than six times the transaction costs. These significant trading profits suggest that market expectations do not fully incorporate the mean reversion in the hog spread, and that there exists a certain degree of inefficiency in the three agricultural commodity futures markets.[12]

Ex-Ante Trading Triggers and Results

Although the ex-post trading profits are significant, they could not have been earned by any traders because Z_{MC}, e_t, and trading triggers are all estimated using data already available in the entire sample period. Because the ratios estimated from the multivariate cointegration are similar to those used by the USDA, we devise ex-ante trading rules using the predetermined Z_{USDA}. Similar to the ex-post trading rules, these trades are triggered when the deviation of USDA-ratios-based hog spread from its mean exceeds 0.25, 0.50, 0.75, or 1.00 times its standard deviation. The trading rules are as follows. For the long position, go long on day *t* by buying 1 pound of lean hog, selling 0.067 bushels of corn, and selling 0.00048 tons of soybean meal simultaneously if

$$\frac{Z_{USDA,t} - u_{1,t-1}(Z_{USDA})}{u_{1,t-1}(Z_{USDA})} < -X\sigma_{1,t-1}(Z_{USDA}) \tag{19}$$

[12]An inevitable question arises here concerning the ability of the term structure to incorporate seasonality. We repeat the ex-post trading simulations based on simple deviations of Z_{MC} from an in-sample trending mean without adjusting for seasonality. *t* test and *F* test results show that these seasonally unadjusted trades' average profits and standard errors are not significantly different. The number of trades, average duration, and percent profitable are also similar. These results seem to indicate that market expectations incorporate seasonality better than they do the mean reversion. This issue could be an interesting topic for future research.

where X is alternately 0.25, 0.50, 0.75, and 1.00; $Z_{USDA,t}$ is the ex-ante hog spread calculated using the USDA ratios at time t, which is $Z_{USDA,t} = Hog_t - 0.067 \times Corn_t - 0.00048 \times Meal_t$; and $u_{1,t-1}(Z_{USDA})$ and $\sigma_{1,t-1}(Z_{USDA})$ are the mean and standard deviation of the hog spread calculated from the first observation in the sample to day $t - 1$. The ex-ante trading simulations start two years after the first observation in the sample in order to provide reliable estimates of $u_{1,t-1}(Z_{USDA})$ and $\sigma_{1,t-1}(Z_{USDA})$. Close the position when the ex-ante hog spread deviation, or the left-hand-side of the above specifications, goes above zero. For the short position, go short on day t by selling 1 pound of lean hog, buying 0.067 bushels of corn, and buying 0.00048 tons of soybean meal simultaneously if

$$\frac{Z_{USDA,t} - u_{1,t-1}(Z_{USDA})}{u_{1,t-1}(Z_{USDA})} > X\sigma_{1,t-1}(Z_{USDA}) \tag{20}$$

Close the position when the ex-ante hog spread deviation goes below zero.

The ex-ante trading results are reported in Table VIII. Compared to the ex-post trade, there are more trades conducted, and the trades tend to be shorter. This is in line with our expectations as the ex-ante trading triggers are exposed to more uncertain fluctuations than the ex-post triggers whose parameters are all estimated in-sample. Ex-ante trades are thus easier to be initiated or closed, causing the number of trades to be higher and trade duration to be shorter. With regard to profitability, there are lower percentages of profitable trades. Short positions with trigger $>0.25\sigma_{1,t-1}$ even have only 48.65% profitable trades, i.e., more money-losing trades than profitable trades. Long positions appear to be more profitable than short positions in light of the percent profitable and average profit, suggesting that the USDA-ratio-based hog spread is skewed to the right. The P values indicate that the average profits are significant at the 0.10 level when the trading triggers are $<-0.75\sigma_{1,t-1}$ and $<-\sigma_{1,t-1}$ for long positions and $>\sigma_{1,t-1}$ for short positions. The fact that the average profits are all positive with some of them being significant provides further evidence of inefficiency in these three agricultural commodity futures markets.[13] Nevertheless, these profits might not be extremely appealing to futures traders for several reasons. First, the average profits are only significant at the 10% level. Second, there is on average only about one (for the $<-0.75\sigma_{1,t-1}$ trigger) or less than one (for the $<-\sigma_{1,t-1}$ and $>\sigma_{1,t-1}$ triggers) trade per year. And lastly, nearly half of all the trades conducted are not profitable.

[13]We also conduct ex-ante trading simulations with trading triggers that include the seasonal factors. The results are not significantly different.

TABLE VIII
Ex-Ante Trading Simulations Based on Reversion to the Estimated Mean of Z_{USDA}

	Open Position on Day t When $(Z_{USDA,t} - \mu_{1,t-1})/\mu_{1,t-1}$ *is*			
	$<-0.25\sigma_{1,t-1}$	$<-0.5\sigma_{1,t-1}$	$<-0.75\sigma_{1,t-1}$	$<-\sigma_{1,t-1}$
Panel A: Long Positions				
Number of trades	40	26	19	10
Average duration	22 days	27 days	56 days	81 days
Percent profitable	57.50%	61.54%	57.89%	60.00%
Maximum profit	\$0.137	\$0.152	\$0.177	\$0.177
Minimum profit	−0.144	−0.098	−0.076	−0.070
Average profit	0.006	0.013	0.049	0.051
Standard error	0.014	0.018	0.032	0.036
P value	0.335	0.238	0.072	0.095
	$>0.25\sigma_{1,t-1}$	$>0.5\sigma_{1,t-1}$	$>0.75\sigma_{1,t-1}$	$>\sigma_{1,t-1}$
Panel B: Short Positions				
Number of trades	37	20	14	9
Average duration	29 days	33 days	78 days	107 days
Percent profitable	48.65%	55%	50%	55.56%
Maximum profit	\$0.153	\$0.153	\$0.172	\$0.189
Minimum profit	−0.139	−0.119	−0.119	−0.082
Average profit	0.002	0.008	0.034	0.048
Standard error	0.017	0.021	0.032	0.033
P value	0.454	0.354	0.154	0.092

Note. $Z_{USDA,t} = \text{Hog}_t - 0.067 \times \text{Corn}_t - 0.00048 \times \text{Meal}_t$. $\mu_{1,t-1}$ and $\sigma_{1,t-1}$ are the mean and standard deviation of Z_{USDA} from first observation to day $t-1$. A long (short) position is established by buying (selling) 1 pound of lean hog and selling (buying) 0.067 bushels of corn and 0.00048 tons of soybean meal in the futures market based on the USDA ratios. Trading triggers are chosen at 0.25, 0.50, 0.75, and 1.00 times $\sigma_{1,t-1}$. A position is closed by executing the opposite trades when the ex-ante hog spread deviation, $(Z_{USDA,t} - \mu_{1,t-1})/\mu_{1,t-1}$, reverts to zero. Trading costs are \$0.0053875 per pound for hog, \$0.0081 per bushel for corn, \$0.355 per ton for soybean meal, and approximately \$0.0061 for trading the Z_{USDA} hog spread on a per pound of lean hog basis. *P* values are from the *t* test of the null hypothesis that the average profit is equal to zero.

To examine the respective performance of trading the three futures contracts, we dissect the profitability of the three components of hog spread in the ex-ante trading simulations with significant profits in Table IX. The transaction costs are divided and allocated to each component. Regarding the average profit, the hog component generates at least 80% of the profits from trading the entire hog spread. From the *P* values, the profits of trading each of the three components are not significant, the profits of trading the three components together, however, are. Regarding the trading risk as measured by the standard error, trading the hog spread appears to have less risk than trading only the hog component. This suggests that, although the hog component of the hog spread

TABLE IX

Profitability of Hog Spread Components for the Ex-Ante Trading Simulations With Significant Trading Profits

	Open Position on Day t When $(Z_{USDA,t} - \mu_{1,t-1})/\mu_{1,t-1}$ *is*							
	$<-0.75\sigma_{1,t-1}$				$<-\sigma_{1,t-1}$			
	Hog Spread	*Hog*	*Corn*	*Meal*	*Hog Spread*	*Hog*	*Corn*	*Meal*
Panel A: Long Positions with Significant Trading Profits								
Average Profit	0.049	0.040	0.104	4.167	0.051	0.041	0.134	2.083
Standard Error	0.032	0.033	0.098	4.652	0.036	0.038	0.102	1.997
P value	0.072	0.121	0.151	0.191	0.095	0.154	0.111	0.162

	$>\sigma_{1,t-1}$			
	Hog Spread	*Hog*	*Corn*	*Meal*
Panel B: Short Positions with Significant Trading Profits				
Average Profit	0.048	0.043	0.090	−2.083
Standard Error	0.033	0.034	0.068	2.125
P value	0.092	0.121	0.112	0.822

Note. Average profit and standard errors are for the components of the hog spread trades described in Table VIII. *P* value is from the *t* test of the null hypothesis that the average profit is equal to zero. The unit for average profit is \$/lb. for hog, \$/bushel for corn, and \$/ton for soybean meal.

trades contributes the majority of the profit, the corn and soybean meal future contracts not only help determine the entry and exit points of the trades, but also reduce the risk of trading the hog contract alone.

SUMMARY AND CONCLUDING REMARKS

Using a multivariate cointegration test approach and adjusting for seasonal factors and trends, we find that hog, corn, and soybean meal futures prices are cointegrated. This suggests that, consistent with the findings of Bessembinder et al. (1995), there are significant tendencies for the hog spread to revert to its long-run equilibrium. In addition, we find only one cointegrating vector, whose coefficients are comparable to the ratios used by the USDA. Our ex-post trading simulations based on the cointegration relations are able to generate significant profits net of transaction costs, suggesting that market expectations as reflected in the futures term structure cannot fully incorporate the mean reversion, and that there exists a certain level of inefficiency in the three futures markets. Results from the ex-ante trading simulations using the USDA ratios also provide some evidence in this regard. Closer examination reveals that, although the majority of the trading profits come from the hog component of the spread, the corn and soybean meal futures contracts help reduce trading risks.

The results of this study are important because they can help hog farmers and policy-makers understand the long-term linkages across the three commodity futures markets and the inefficiencies inherent in the markets in order to better manage risk exposures, increase operations profitability, and formulate effective regulations and policies. For futures traders, our findings that market expectations as reflected in the futures term structure do not fully incorporate the mean-reverting trends may help them devise better trading strategies to achieve higher portfolio return and lower risk exposure.

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