The Soybean Crush Spread: Empirical Evidence and Trading Strategies

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This article finds that deviations of the soybean crush spread from its long-run equilibrium were transitory during the sample period from January 1985 through February 1995. This equilibrium is characterized by strong seasonality and by a persistent uptrend in soymeal and soyoil prices relative to soybean prices. A tendency also exists for the crush spread to revert toward its most recent 5-day average. Simulations demonstrate that trading rules based on these results would have been profitable. © 1999 John Wiley & Sons, Inc. Jrl Fut Mark 19: 271–289, 1999

INTRODUCTION

The soybean futures crush spread, which stems from the process by which soybeans are crushed into soymeal and soyoil, is a commonly traded spread. Two major strands exist in the current literature on the soybean crush spread. The first examines the possibility that commercial processors can lock in above normal crush margins by buying soybean futures and by simultaneously selling soymeal and soyoil futures (hereafter meal and oil futures) when soybean futures are cheap relative to meal and oil

The author is grateful to James Zeitler for outstanding programming assistance and to an anonymous referee for helpful comments.
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The Journal of Futures Markets, Vol. 19, No. 3, 271–289 (1999)

CCC 0270-7314/99/030271-19

futures.[1] After locking in attractive crush margins in the futures markets, processors would take delivery of and crush soybeans and deliver meal and oil to close short futures positions. Kenyon and Shapiro (1976) and Frank et al. (1989) demonstrate that processors could have enhanced returns and reduced risk by locking in above normal crush margins in the futures markets.

The second strand of the literature examines trading rules that exploit unusual levels of the futures crush spread by buying the crush spread—buying meal and oil futures and selling soybean futures—when the crush spread is low, and by selling the crush spread—selling meal and oil futures and buying soybean futures—when the crush spread is high.[2] Johnson et al. (1991) simulate trading strategies in which on the 15th of each month from 1966 through 1988, traders buy or sell the crush spread depending on whether it is a given threshold below or above its 6-month moving average, respectively. Positions are closed out at predetermined intervals ranging from 1-1/2 to 6 months later. After carefully accounting for transactions costs, the authors find that their trading strategies would have been profitable for longer intervals, but not for shorter intervals.

Along similar lines, Rechner and Poitras (1993) examine intra-day trading strategies where, based on deviations of the crush spread at the opening of trading from the previous day's close, the crush spread is either bought or sold. The position is reversed on the same day at the close. These authors find that floor traders could have earned profits net of transaction costs following these trading rules.

In these studies, a major underlying, yet not directly tested, premise is that the soybean crush spread reverts to particular levels, and that deviations from these levels are transitory and can be exploited. The present article extends the literature by examining directly whether the crush spread tends to revert both toward a stable long-run equilibrium and toward its most recent 5-day average, and whether such patterns give rise to profitable trading opportunities. To these ends, this article examines whether the crush spread is a cointegrating relationship, within a GARCH (generalized autoregressive conditional heteroskedasticity) framework that allows for time-varying volatility and excess kurtosis that characterize the crush spread. The article examines also whether the

[1]Studies that examine whether attractive margins can be locked in via futures contracts in other markets include Kenyon and Clay (1987) in hogs, corn, and soymeal and Schroeder and Hayenga (1988) in finished cattle, feeder cattle, and corn.

[2]Along similar lines, Park and Switzer (1996) examine strategies for trading Treasury futures spreads and demonstrate that profitable trading strategies can be devised for the Treasury note over Treasury bond futures (NOB) spread and the 5-year Treasury note futures over the Treasury bond futures (FOB) spread.

crush spread tends to revert toward its 5-day average. Finally, this article examines whether trading rules based on the empirical results would have been profitable over the sample period.

The results indicate that the crush spread represents an equilibrium relationship once the seasonality and the pronounced upward trend of the crush spread from 1985–1995 are modeled. In addition, the results also demonstrate that the crush spread reverts toward its most recent 5-day average. Finally, simulation results indicate that trading rules based on these empirical results would have been profitable.

The article is laid out as follows: The second section of the article examines the data, discusses the methodology for examining both whether the soybean crush spread is a cointegrating relationship and whether the crush spread reverts to its recent 5-day average and provides estimation results. The third section simulates trading strategies based on the empirical results, and the final section summarizes the overall results.

THE SOYBEAN CRUSH SPREAD AS LONG-RUN EQUILIBRIUM

This section assesses the time series properties of the soybean futures complex and the soybean futures crush spread, which are traded at the Chicago Board of Trade. The previous literature sets the soybean crush spread equal to the USDA's (1988) estimate that one bushel or 60 pounds of soybeans produces an average of 48 pounds of meal and 11 pounds of oil. The USDA's calculation of the gross crush margin is,

$$\begin{aligned} \text{GCM} = {} & [((\text{Meal}^*48)/2000 \text{ lbs.}) + ((\text{Oil}^*11)/100 \text{ lbs.})] \\ & - \text{Soybean}, \end{aligned} \tag{1}$$

where GCM is the gross crush margin, Meal is the futures price of meal per ton, Oil is the futures price of oil per 100 pounds, and Soybean is the futures price of soybeans per bushel. Figure 1 shows the USDA estimate of the gross crush margin over the sample period from January 1985 through February 1995 using the close of nearby futures contracts until the first day of the month prior to the expiration month, at which time the next contracts are followed.[3] The figure indicates that the gross

[3]Soybeans have no intrinsic value beyond the value of the meal and oil that are produced from crushing.

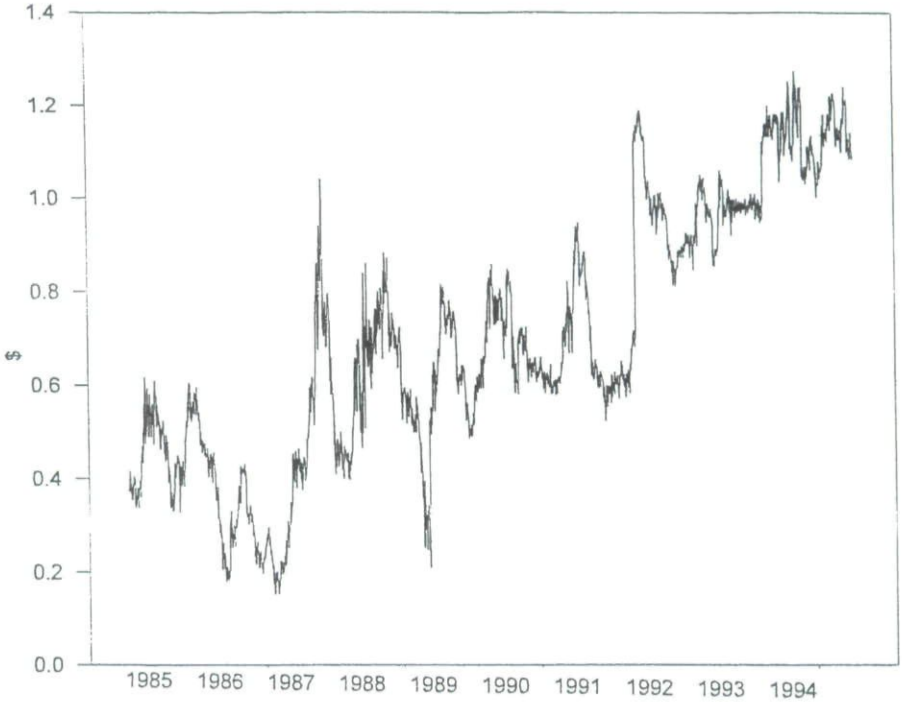

FIGURE 1
The soybean crush spread (USDA estimates)

crush margin has trended upward during the sample period and has oscillated around this upward trend.[4]

From a trading perspective, a key issue is whether soybean, meal and oil futures prices tend to revert reliably toward a particular relationship, and whether deviations from such a relationship present favorable risk-reward trade opportunities. A priori, the soybean crush spread might not necessarily represent a long-run equilibrium for a variety of reasons. First, the amount of meal and oil and the quality of the oil produced by a bushel of soybeans varies according to growing conditions. Second, changes in crushing capacity relative to demand can affect profit margins from crushing soybeans. Along these lines, some analysts attribute the upward trend in the crush spread over the sample period to a reduction in crushing capacity relative to demand. Finally, decisions by major oilseed importing countries to import soybeans rather than meal and oil to support their local processing industries can affect the crush spread. Rather than

[4]Johnson et al. (1991) note the upward trend of the crush spread over their sample period from 1966 to 1988 and for this reason use deviations from a 60-month moving average as the basis for trading. Rechner and Poitras (1995) also observe an upward trend in the crush spread in their second subsample from June 1987 to July 1991.

TABLE I

Augmented Dickey-Fuller Unit Root Tests of the Levels and the Changes of the Soybean Complex (Daily data from January 1985–February 1995)

Variable	Coefficient Estimate	T-statistic
Soybean	-.005	-1.38
Meal	-.003	-1.00
Oil	-.002	-.94
ΔSoybean	-.985	-10.76
ΔMeal	-.995	-11.83
ΔOil	-.983	-15.00

These tests involve regressing the first difference of each of the variables on a constant, three lags of the dependent variable, and the lagged level of the dependent variable. The null hypothesis of non-stationary is rejected at the five and one percent levels if the t-statistic on the lagged level is less than -2.86 and -3.43, respectively.

imposing on the data the USDA estimates of the crush spread, the strategy is to estimate the relationship among the levels of soybean, meal and oil futures prices to determine whether a stable relationship exists, and then to examine whether this relationship is meaningful from a trading perspective in that deviations are reliably short-lived.

The analysis of the crush spread is conducted in price levels and price changes rather than in log levels and log price changes because the fundamental arbitrage is in dollar amounts—a given deviation from the long run equilibrium crush spread is no more or less compelling at higher or lower levels of soybean complex prices. The qualitative results are unchanged when the analysis is conducted in log levels and log price changes. The soybean, meal and oil futures contracts used in this article are the front month contract until the first day of the month prior to the expiration month of the front contract, at which point the next contract is followed.[5] Price changes on the days of contract switches are calculated using the old contract to avoid spurious price changes.

Before investigating relationships among the soybean complex, establishing the order of integration is important. Augmented Dickey-Fuller unit root tests are displayed in Table I. These unit root tests involve re-

[5]All three contracts trade for expiration months of January, March, May, July, August, and September. Soybean futures also trade for expiration in November, while meal and oil futures also trade for expiration in October and December. The only exception to the above rule for contract switching is that in the beginning of August, when the September soybean futures contract is dropped and the November soybean futures contract is picked up, the September meal and oil futures are dropped and the December meal and oil futures are picked up. This is consistent with the tendency for the crush spread in the new crop to be traded in November soybeans versus December meal and oil.

gressing the first difference of each variable on a constant, the lagged level of itself, and four lags of the dependent variable. The hypothesis of a unit root in levels is rejected at the 5% and 1% levels if the coefficient on the lagged level is significantly less than zero using the Dickey-Fuller (1979) critical t-statistic levels of -2.86 and -3.43, respectively. The regressions are estimated with White's (1980) correction for heteroskedasticity. Including four lags of the dependent variable in the model is sufficient to eliminate autocorrelation. The tests of whether the first differences are stationary involve regressing the second difference of soybean, meal and oil futures prices on a constant, the lagged first difference of itself and four lags of the dependent variable. The results in Table I indicate that soybeans, meal and oil are stationary only after first-differencing.

Whether a cointegrating relationship exists among the levels soybean, meal, and oil futures prices is examined next. To the extent that such a relationship exists, soybean, meal and oil futures prices can diverge from each other in the short run, but tend to revert toward a long-run equilibrium over time. The relationship among the levels of the soybean complex is determined by estimating

$$\begin{aligned}\text{Soybean}_t &= \beta_0 + \beta_1 \text{ Meal}_t + \beta_2 \text{ Oil}_t + \beta_3 \text{ Trend} \\ &\quad + \sum_{i=4}^{14} \beta_i \text{ Monthly Dummies} + \mu_t, \qquad (2)\end{aligned}$$

where Soybean is the soybean futures price in \$ per bushel, Meal is the soymeal futures price in \$ per ton, Oil is the soybean oil futures price in \$ per 100 lbs., Trend is a linear time trend, and Monthly Dummies are eleven seasonal dummies that take on the value one for each month from January through November, or zero, otherwise. Because the equation is specified with soybean prices as the dependent variable and meal and oil prices as independent variables, the fitted value can be interpreted as the estimate of the trend and seasonally adjusted reverse crush spread.[6]

The OLS estimates of the relationship are shown in Table II and are reasonably close to the USDA estimates of the crush spread. A \$1 increase in the price of meal is associated with a 2.43 cent increase in the price of soybeans (compared to the USDA estimate of 2.4 cents), and a \$1 increase in the price of 100 lbs. of oil is associated with an 8.9 cent increase in the price of soybeans (compared to the USDA estimate of 11

[6]The qualitative results are little changed when the dependent and independent variables are switched.

TABLE II

Estimates of The Soybean Crush Spread in Levels (Daily Data from January 1985–February 1995)

$$\underset{}{\text{Soybean}_t} = \underset{(.0151)}{.0373} + \underset{(.0001)}{.0243}\ \text{Meal}_t + \underset{(.0001)}{.0891}\ \text{Oil}_t + \underset{(.00003)}{-.00026}\ \text{TREND} + \underset{(.009)}{.033}\ \text{JAN}$$

$$+ \underset{(.009)}{.109}\ \text{FEB} + \underset{(.009)}{.109}\ \text{MAR} + \underset{(.010)}{.112}\ \text{APR} + \underset{(.010)}{.108}\ \text{MAY} + \underset{(.010)}{.110}\ \text{JUN}$$

$$+ \underset{(.010)}{.027}\ \text{JUL} \underset{(.009)}{-.023}\ \text{AUG} \underset{(.010)}{-.090}\ \text{SEP} \underset{(.011)}{-.040}\ \text{OCT} \underset{(.010)}{-.082}\ \text{NOV}$$

Soybean, Meal and Oil are front contract soybean, soymeal and soybean oil futures closing prices. Trend is a linear time trend and eleven monthly seasonal dummy variables are included in the model. Standard errors are included in parentheses.

cents).[7] The significantly negative coefficient on the trend indicates that over the sample period, soybean prices fell relative to meal and oil prices, resulting in an upward trend in the crush spread over the sample period of roughly 6 1/2 cents per year. This finding suggests that buying the crush spread might be preferred to selling it, ceteris paribus. The crush spread also demonstrates a strong seasonal pattern, tending to be about 20 cents lower during the February to June period than the September to November period, as soybean prices rise relative to meal and oil prices prior to growing season and then fall relative to meal and oil prices after the growing season. Analysts attribute this phenomenon to soybean processors competing for relatively scarce soybean supplies prior to the growing season and to the increased abundance of soybeans after the harvest.[8] The deviations from the estimates of the crush spread—minus the residual of Eq. 2—are shown in Figure 2.[9] As can be seen, the upward trend

[7]Using standard inference procedures, the hypothesis that these estimates are equal to those of the USDA is easily rejected.

[8]Part of this apparent seasonality reflects the fact that different contracts are followed throughout the year. In particular, in early August the (new crop) November soybean and December meal and oil contracts are being picked up, while September futures contracts, which reflect conditions prior to the harvest, are dropped. The new crop crush spread reflects the increased abundance of soybeans after the harvest.

[9]Again, because Eq. 2 specifies soybean prices as the dependent variable and meal and oil prices as independent variables, the residual can be interpreted as the deviation from the trend and seasonally adjusted reverse crush spread. Thus, minus the residual of Eq. 2 can be interpreted as the deviation from the trend and seasonally adjusted crush spread.

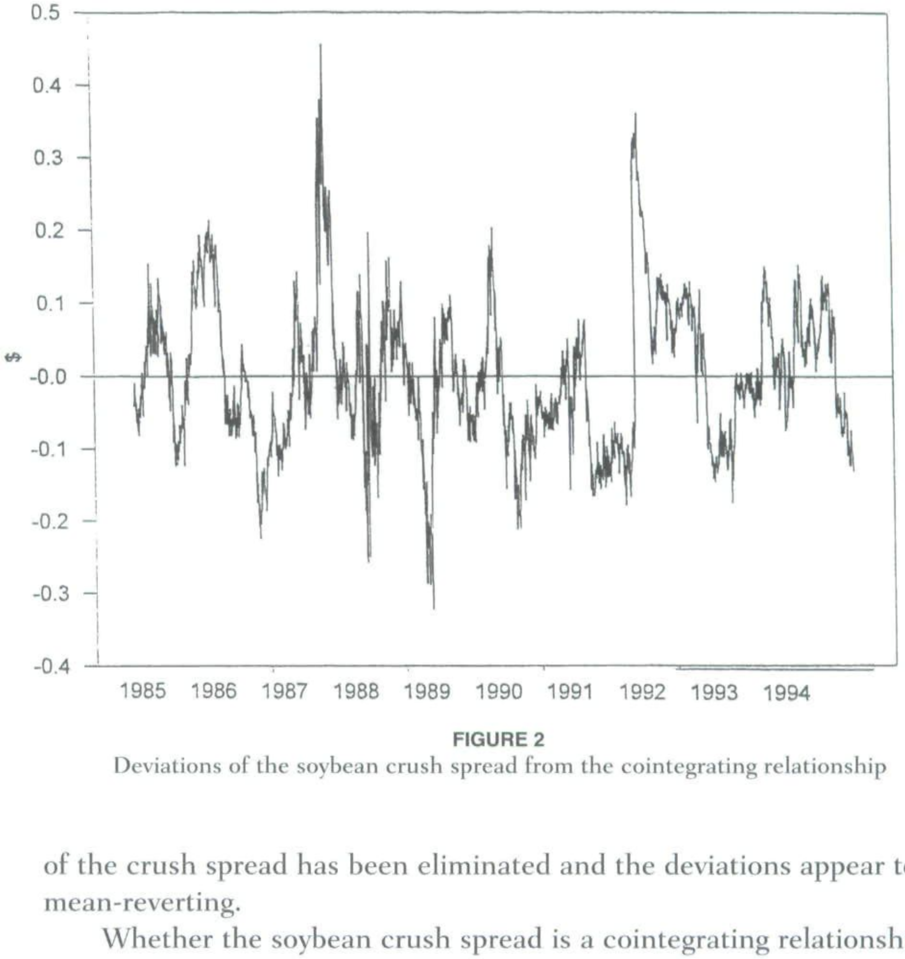

FIGURE 2
Deviations of the soybean crush spread from the cointegrating relationship

of the crush spread has been eliminated and the deviations appear to be mean-reverting.

Whether the soybean crush spread is a cointegrating relationship is examined by testing whether deviations from the estimates of the crush spread levels are stationary. Engle and Granger (1987) tests for stationarity are conducted on the deviation from the crush spread by estimating

$$\Delta\text{CRUSHDEV}_t = \alpha_0 + \alpha_1\ \text{CRUSHDEV}_{t-1} + \sum_{i=1}^{3} \beta_i\ \Delta\text{CRUSHDEV}_{t-i} + \eta_t, \quad (3)$$

where CRUSHDEV is the deviation from the estimates of the crush spread. The null hypothesis of the nonstationarity or the non-cointegration of the crush spread is rejected if α_1 is significantly less than zero, using the Engle and Granger (1987) critical levels. Including three lags of the independent variable in the model is sufficient to eliminate autocorrelation. Preliminary estimates of equation 3 indicate the presence of time-varying volatility and excess kurtosis in the residuals. As a result, the error term of Eq. 3 is modeled as having a t-distribution

$$\eta_t \sim t\ (0,\ h_t,\ \Phi), \tag{4}$$

with a mean of zero, a conditional variance, h_t and $1/\Phi$ degrees of freedom.

The conditional variance is modeled as a GARCH process,

$$h_t = \gamma_0 + \gamma_1 h_{t-1} + \gamma_2 \eta_{t-1}^2, \tag{5}$$

where η_{t-1}^2 is the lagged squared innovation of the first difference of the crush spread. Eq. 5 specifies that the variance of the innovation of Eq. 3 follows an autroegressive process that is shocked by the lagged squared innovation of the first difference of the crush spread. Eqs. 3, 4, and 5 are jointly estimated using maximum likelihood.[10]

The estimation results in Table III indicate that the hypothesis that the soybean crush spread is not a cointegrating relationship is rejected. The coefficient on the lagged level of the deviation from the crush spread is significantly less than zero at the one percent level, as the t-statistic is -3.79, compared with the Engle and Granger (1987) one percent critical value of -3.73. The point estimate of $-.0148$ on the lagged level of the deviation from the crush spread indicates that half-lives of shocks from the cointegrating relationship are about 46 days.[11] Thus, while deviations from the equilibrium level of the crush spread are not permanent, the movement back toward equilibrium is fairly gradual.[12] The first two lags of the crush spread change are both significantly negative, indicating that an increase in the growth rate of the crush spread typically is followed by subsequent reductions in the growth rate. The Box-Ljung Q statistic with 12 lags indicates that the standardized residual is not serially correlated.

Turning to the conditional volatility estimates, the lagged variance of the crush spread innovation enters the volatility equation significantly with a coefficient of 0.87, while the coefficient on the lagged squared innovation enters significantly with a coefficient of about 0.09. These estimates imply that the conditional volatility is stationary, as estimates of $(\gamma_1 + \gamma_2)$ are equal to about .96, implying that shocks to the variance of the crush spread have half-lifes of about 17 days. The estimate of the

[10]The above model specification allows lagged differences of the components of the crush spread to enter only through lagged first differences of the crush spread. To test whether this specification is overly restrictive, the model was also estimated by separately adding three lags of the first difference of each of the components of the soybean complex. Although some of the lags of the components entered the model significantly, the overall results were unchanged.

[11]The half-life of a shock is equal to $\ln(.5)/\ln(1 + (\alpha_1)$.

[12]Models were also estimated that allow both asymmetric mean reversion and mean reversion to be stronger following larger absolute deviations from the long run equilibrium. These models did not uncover nonlinearities in the adjustment pattern.

TABLE III

Tests of Whether the Soybean Crush Spread is a Cointegrating Relationship Within a GARCH Volatility Process Assuming a T-Distributed Error Term

$$\Delta CRUSHDEV_t = \underset{(.00030)}{.00005} - \underset{(.0039)}{.0148}\ CRUSHDEV_{t-1} - \underset{(.0186)}{.2034}\ \Delta CRUSHDEV_{t-1}$$

$$- \underset{(.0187)}{.0548}\ \Delta CRUSHDEV_{t-2} - \underset{(.0180)}{.0286}\ \Delta CRUSHDEV_{t-3}$$

$$h_t = \underset{(.0000)}{.0000} + \underset{(.0188)}{.8675}\ h_{t-1} + \underset{(.0160)}{.0909}\ \eta^2_{t-1}$$

$$\Theta = 4.05\ (.2975)\ ,\ Q(12) = 16.77,\ \text{Log Likelihood} = 8248$$

CRUSHDEV is the residual from the estimates of equation 2, which specifies the level of soybean prices as a function of a constant, the level of meal and oil prices, 11 monthly seasonal dummies and a linear time trend. Θ is the number of degrees of freedom estimated for the assumed t-distribution, with the standard error of the estimate in parentheses. Q(12) is a Box-Ljung test for autocorrelation of the first 12 lags of the standardized residual. Standard errors are in parentheses.

inverse of the degrees of freedom of the t-distribution is highly statistically significant and indicates a substantial degree of excess kurtosis.[13]

In the spirit of Johnson et al. (1991), who simulate trading strategies that exploit deviations of the crush spread from its recent central tendency, the above model is reestimated with the deviation from the long run equilibrium replaced by the deviation of the crush spread from its (lagged) 5-day average. Because the specification is no longer an error correction model, standard t-statistics can be used to determine whether the crush spread reverts to its 5-day average. The other aspects of the specification remain identical to the previous model.

The results shown in the lower panel of Table IV indicate that the crush spread tends to revert significantly toward its 5-day average. The

[13]The model was also estimated with separate variables for positive and negative crush spread innovations in the conditional volatility equation. Conditional volatility asymmetries were not found.

TABLE IV

Tests of Whether the Soybean Crush Spread Reverts to its 5-Day Moving Average Within a Garch Volatility Process Assuming a T-Distributed Error Term

$$\Delta CRUSHDEV_t = \underset{(.00030)}{.00005} - \underset{(.0899)}{.1854}\, DEVMA5_{t-1} - \underset{(.0738)}{.0655}\, \Delta CRUSHDEV_{t-1}$$

$$+ \underset{(.0560)}{.0462}\, \Delta CRUSHDEV_{t-2} + \underset{(.0367)}{.0331}\, \Delta CRUSHDEV_{t-3}$$

$$h_t = \underset{(.0000)}{.0000} + \underset{(.0191)}{.8666}\, h_{t-1} + \underset{(.0160)}{.0898}\, \eta^2_{t-1}$$

$$\Theta = 4.00\ (.2924)\ ,\ Q(12) = 13.41,\ \text{Log Likelihood} = 8243$$

CRUSHDEV is the residual from the estimates of equation 2, which specifies the level of soybean prices as a function of a constant, the level of meal and oil prices, 11 monthly seasonal dummies and a linear time trend. DEVMA5 is the deviation of the crush spread from its 5-day average. Θ is the number of degrees of freedom estimated for the assumed t-distribution, with the standard error of the estimate in parentheses. Q(12) is a Box-Ljung test for autocorrelation of the first 12 lags of the standardized residual. Standard errors are in parentheses.

coefficient estimate of -0.185 on the deviation of the crush spread from its 5-day average indicates that the half-life of such deviations is about 3 days. The other coefficient estimates are little changed from the previous specification, with the exception that the lagged first-differences of the crush spread no longer enter the model significantly.

The overall empirical findings are that the crush spread reverts both toward its long run equilibrium and toward its most recent 5-day average. In view of the much slower adjustment of the crush spread toward its long run equilibrium compared to the adjustment toward its most recent 5-day average, the latter may be more important from a trading perspective.

TRADING RULE SIMULATIONS

The Rules and Assumptions

In this section the significance for traders of the mean-reverting tendencies of the crush spread is assessed by simulating trading rules that exploit these tendencies. The simulations are performed in-sample and thus provide information as to whether the degree of mean reversion during the sample period could have been the basis for successful crush spread trading strategies. The estimates of the equilibrium level of the crush spread in the previous section imply that trades of 12 meal contracts and 8 oil contracts against 10 soybean contracts would replicate the physical crushing process.[14] However, while processors often hedge using exact position sizes, floor traders and speculators typically trade the crush spread with one contract of meal and oil against one contract of soybeans. Consistent with the latter, the crush spread is quoted, and traded as a spread, at the Chicago Board of Trade in 1-1-1 contract sizes. As a result, the simulations are performed with one soybean contract against one contract of meal and oil.[15] Thus, the value of a long crush spread position is equal to the price of one meal futures contract (in $/ton) times the 100 ton contract size plus the price of one oil futures contract (in $/100 lbs.) times the 60,000 lbs. contract size minus the price of one soybean futures (in $/bushel) times the 5000 bushel contract size.[16]

An important finding of the last section was that the crush spread tends to revert toward its long run equilibrium level (subsequently referred to as fair value). An implication of this finding is that when the crush spread is low relative to fair value, traders should buy the crush spread to profit from a tendency to rise toward fair value. Alternatively, if the crush spread is high relative to fair value, traders should sell the crush spread to profit from a tendency to fall toward fair value. The other major finding of the previous section is that the crush spread tends to revert toward its (lagged) 5-day average. Hence, another trading strategy would

[14]The exact position sizes come from the estimates of the cointegrating relation in table 3. One soybean futures contract or 5000 bushels of soybeans can be crushed into 121.5 tons (243,000 lbs.) of meal and into 44,500 lbs. of oil. Given 100 ton meal and 60,000 lb. contract sizes, 10 soybean futures contract could be crushed into 12 meal futures contracts and 8 oil futures contracts. These estimates are somewhat different than the USDA (1988) estimates, which imply trading one soybean contract against 1.2 meal and .9 oil futures contracts.

[15]Johnson et al. (1991) simulate trading strategies with 1-1-1 contract sizes, while Rechner and Poitras (1993) use 10-12-9 contract sizes. The trading simulation results in the present article are qualitatively similar when the crush spread traded with 10 soybean contracts against 12 meal and 8 oil contracts.

[16]Again, long crush spread positions are long meal and oil and short soybeans and represent bets that the crush spread will rise. Short crush spread positions are short meal and oil and long soybeans.

be to buy the crush spread when it is low relative to its 5-day average, and to sell the crush spread when it is high relative to its 5-day average.

The following trading rules based on combinations of the above principles are simulated.

Buy Crush Spread if :
1) Crush Spread is less than Fair Value by ϕ and/or
2) Crush Spread is less than 5-Day Average by κ

Close Long Crush Spread Position if:
Crush Spread is greater than 5-Day Average by η

where ϕ and κ are filters that trigger buying the crush spread and η is a filter that triggers exiting long positions. These rules establish long crush spread positions at the close when the closing crush spread is either less than fair value by an amount ϕ, or below its recent 5-day average by an amount κ, or some combination of the two. As the criteria for entering trades becomes more stringent, fewer trades are entered, but the trades should be more profitable. Long positions are exited when the crush spread moves above its 5-day average by an amount η. The exit rules are based on 5-day averages and not on fair value considerations because the relatively slow mean reversion of the crush spread toward its long run equilibrium would cause exit rules based on fair value to be far less binding at reasonable thresholds than exit rules based on 5-day averages.

Simulations involving selling the crush spread are based on combinations of the following filters.

Sell Crush Spread if :
1) Crush Spread is greater than Fair Value by ϕ and/or
2) Crush Spread is greater than 5-Day Average by κ

Close Short Crush Spread Position if:
Crush Spread is less than 5-Day Average by η

where again ϕ and κ are thresholds or filters that trigger short positions and η is a filter that triggers an exit from a short position. These trading rules establish short crush spread positions when the crush spread is either above fair value by an amount, ϕ, or when the crush spread is above its recent 5 day average by an amount, κ, or some combination of the two. Traders exit short positions when the crush spread falls below its recent 5-day average by an amount, η.

These trading rules are "value based" in the sense of attempting to buy low—when the crush spread is below its 5-day average or below fair value—and attempting to sell high—when the crush spread is above its

5-day average or above fair value—and profit from the tendency of the crush spread to revert toward either its fair value or toward its 5-day average. These rules contrast with trend-following rules, which are less oriented toward the levels at which trades are entered, and more oriented toward the direction of recent changes. An example of a common trend following rule would be to buy the crush spread when it moves above its recent 5-day average (and an upward trend is established) and to exit the long position when the crush spread falls below its 5-day average (and the upward trend has been broken). Unreported results indicate that such trend following rules would not have been profitable. Given the mean reversion of the crush spread, it is not surprising that buying the crush spead on strength and selling the crush spread on weakness is not a profitable trading strategy.

The simulations are conducted under the following assumptions. Trades are executed at the closing prices based on combinations of the above filters at closing prices. Trades are entered in the near-term contracts and are rolled forward on the first day of the month prior to the expiration month. Returns are adjusted for contract rollovers.[17] Similar to other studies of the crush spread, transactions costs for each commodity are assumed to consist of both slippage and brokerage costs. Slippage is assumed to be equal to two price ticks per round trip. Because price ticks for beans, meal and oil are 1/4 cent per bushel, 10 cents per ton, and 1 cent per 100 pounds, respectively, this translates into round trip slippage costs of \$25, \$20, and \$12, respectively. Commissions are assumed to be \$15.50 per round trip per commodity, consistent with commissions currently charged by discount brokers.[18] Adding slippage and commisions, the roundtrip transaction cost of a crush spread trade amounts to \$103.50.[19]

Trading Simulation Results

Tables V and VI present the simulation results for crush spread purchases and sales, respectively, over the sample period from January 1985 through February 1995. The results are presented for various combinations of

[17]This adjustment subtracts any premium or adds any discount on the new contract relative to the old contract, consistent with traders rolling from the old to the new contract on the first day of the month prior to the expiration month.
[18]The author is aware of one full service commodities brokerage firm that currently charges \$15 1/2 per round turn.
[19]The simulations assume that initial margin is met by posting Treasury bills and does not entail any cost. The simulations also abstract from any potential costs associated with meeting variation margin calls.

TABLE V

Trading Rule Simulation Results: Long Crush Spread Trades (January 1985–February 1995)

Entry Conditions	Deviation from 5 Day Average is not a criteria	Crush Spread is $100 less than 5 Day Average	Crush Spread is $200 less than 5 Day Average	Crush Spread is $300 less than 5 Day Average
Fair Value is not a criteria	--	27	231	355
		406	569	1092
		65%	70%	73%
		1802/-1404	1248/-1280	1825/-2068
		7/23	33/84	109/130
		112	37	15
Crush Spread is less than Fair Value	-5	79	477	603
	335	419	443	1048
	54%	72%	84%	77%
	1618/-1441	1802/-1091	1320/-398	1825/-1398
	5/16	7/28	52/31	97/119
	140	74	25	13
Crush Spread is .1 less than Fair Value	62	146	616	656
	266	323	400	772
	59%	75%	92%	90%
	819/-859	1214/-669	1172/-3.5	1825/-901
	5/17	6/29	42/12	55/217
	58	32	13	10
Crush Spread is .2 less than Fair Value	279	361	738	832
	384	533	339	223
	89%	83%	100%	100%
	819/-432	1214/-282	1088/314	1088/680
	5/10	6/8	45/na	6/na
	9	6	5	3
Exit Conditions	Crush Spread is $100 greater than 5 Day Average	Crush Spread is $100 greater than 5 Day Average	Crush Spread is $200 greater than 5 Day Average	Crush Spread is $300 greater than 5 Day Average

The entry conditions are displayed across the top and on the left side of the table. The exit conditions are displayed across the bottom of the table. Each entry from top to bottom displays the average profit in dollars, the standard deviation of profits, the percentage of profitable trades, the maximum profit/maximum loss, the number of days winning/losing trades are held, and the number of trades.

filters for entry and exit rules. The long crush spread trades are shown in Table V. The filters for entering long crush spread positions based on fair value considerations are that the crush spread is less than fair value, .1 less than fair value and .2 less than fair value. These filters correspond

TABLE VI

Trading Rule Simulation Results: Short Crush Spread Trades (January 1985–February 1995)

Entry Conditions	Deviation from 5 Day Average is not a criteria	Crush Spread is $100 greater than 5 Day Average	Crush Spread is $200 greater than 5 Day Average	Crush Spread is $300 greater than 5 Day Average
Fair Value is not a criteria	–	33 284 69% 732/-915 8/16 113	185 362 73% 907/-503 22/21 37	185 549 67% 896/-1143 43/46 15
Crush Spread is greater than Fair Value	-3 275 55% 1227/-1062 6/12 147	65 311 68% 1227/-644 7/16 73	218 378 81% 1227/-503 16/21 31	385 461 82% 1227/-315 25/49 11
Crush Spread is .1 greater than Fair Value	105 223 70% 712/-322 5/6 15	151 257 72% 732/-278 6/10 8	345 315 88% 908/-166 15/6 5	499 422 88% 1043/-132 21/na 3
Crush Spread is .2 greater than Fair Value	65 205 60% 519/-209 5/6 15	128 281 63% 732/-166 6/10 8	302 420 80% 908/-166 15/6 5	366.5 428 100% 855/57 21/na 3
Exit Conditions	Crush Spread is $100 less than 5 Day Average	Crush Spread is $100 less than 5 Day Average	Crush Spread is $200 less than 5 Day Average	Crush Spread is $300 less than 5 Day Average

The entry conditions are displayed across the top and on the left side of the table. The exit conditions are displayed across the bottom of the table. Each entry from top to bottom displays the average profit in dollars, the standard deviation of profits, the percentage of profitable trades, the maximum profit/maximum loss, the number of days winning/losing trades are held, and the number of trades.

to the residuals of the estimates of the long-run equilibrium crush spread being below 0, −.1 and −.2, respectively. The filters for entering long positions based on the 5-day averages are that the value of the crush spread position comprised of long positions in one meal and one oil futures contracts and short one soybean futures is $100, $200, and $300 less than its 5-day average. The exit rules correspond to the entry rules based on the 5-day averages and stipulate that trades are closed out when the value of the long position in the crush spread is $100, $200, and $300 greater than its 5-day average.

Tables V and VI are set up as follows. The entry rules based on fair value considerations are shown in the far left of the table, while entry rules based on deviations from 5-day averages are shown in the top of the table. Exit rules are displayed at the bottom of the table. For each combination of entry and exit rules, displayed from top to bottom are: the average $ profit, the standard deviation of profits, the percentage of profitable trades, the maximum profit/maximum loss, the average number of days winning/losing trades are held, and the number of trades entered.

Table V indicates that long trades entered solely based on deviations from 5-day averages (shown in the first row) would have been profitable on average over the sample period, with average profits ranging from $27 per trade to $355 per trade, and with profitable trades occurring about 2/3 of the time. In addition, long crush spread trades based on only fair value considerations (shown in the first column) would have been profitable only when the crush spread is .10 or .20 below fair value, with average profits ranging from $62 to $279. Profitability is increased when entry rules based on 5-day averages are augmented with entry rules based on fair. For example, when the crush spread is below fair value, or either .1 or .2 below fair value and the crush spread is $200 or $300 less than its 5-day average (rows 2, 3 and 4, columns 3 and 4), profits range from $477 to $832, with percentage of profitable trades ranging from 77% to 100%. The table also shows that for each trading rule, the maximum gains are typically greater than the maximum losses and the number of days that profitable versus losing trades are held do not differ systematically.

Short crush spread trades are based on criteria similar to long crush spread trades. The filters for entering short crush spread positions based on fair value considerations are that the crush spread is greater than fair value, .1 greater than fair value and .2 greater than fair value. Again, these filters correspond to the residuals of the estimates of the long-run equilibrium crush spread being above 0, .1, and .2, respectively. The filters for entering short crush spread positions based on its 5-day average are that the value of the short crush spread position comprised of short positions in one meal and one oil futures contracts and long one soybean futures is \$100, \$200 and \$300 greater than its 5-day average. The exit rules correspond to the entry rules based on the 5-day averages and stipulate that trades are closed out when the value of the short position in the crush spread is \$100, \$200, and \$300 less than its 5-day average.

Short crush spread trades, shown in Table VI, are generally profitable as well. Short crush spread trades based solely on thresholds for the deviation of the crush spread from its 5-day average (shown in the first row) are all profitable on average, while short crush spread trades based solely on fair value considerations (shown in the first column) again are mixed. Combining the criteria that short positions are entered if the crush spread is either greater than fair value, or .1 or .2 greater than fair value with the criteria that the crush spread is \$200 or \$300 above the 5-day average (rows 2,3 and 4 and columns 3 and 4) results in positive average profits ranging from \$218 to \$499, with percentage of profitable trades ranging from 80% to 100%. Overall, while short trades based on fair value considerations are not always profitable by themselves, adding fair value conditions to entry conditions based on 5-day averages substantially increases profitability. In addition, the profitability of long crush spread trades generally exceeds the profitability of short crush spread trades, consistent with the upward trend in the crush spread over the sample period.

SUMMARY

This article demonstrates that the soybean crush spread reverts to a long-run equilibrium that is characterized by strong seasonality and by an upward trend over the sample period. In addition, the soybean crush spread tends to revert toward its most recent 5-day average. Simulations of trading rules based on these empirical results suggest that together these rules would have been profitable during the sample period. Because these simulations are conducted in-sample, the results do not necessarily have implications for market efficiency but rather indicate that the degree of mean reversion during the sample period would have been adequate to give rise to profitable trading strategies. The results also suggest that market participants trading the crush spread on the basis of fundamentals could have obtained an edge by augmenting their trading decisions with information concerning the current level of the crush spread relative to both its long-run equilibrium level and its recent center of gravity.

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