Journal of Agricultural and Applied Economics, 37,1(April 2005):65–78

Can Multiyear Rollover Hedging Increase Mean Returns?

Byung-Sam Yoon and B. Wade Brorsen

Both market advisors and researchers have often suggested multiyear rollover hedging as a way to increase producer returns. This study determines whether rollover hedging can increase expected returns for producers. For rollover hedging to increase expected returns, futures prices must follow a mean-reverting process. To test for the existence of mean reversion in agricultural commodity prices, this study uses a longer set of price data and a wider range of test procedures than past research. With the use of both the return predictability test from long-horizon regression and the variance ratio test, we find that mean reversion does not exist in futures prices for corn, wheat, soybean, soybean oil, and soybean meal. The findings are consistent with the weak form of market efficiency. Simulated trading results for 3-year rollover hedges provide additional evidence that the expected returns to the rollover hedging strategies are not statistically different from the expected returns to routine annual hedges and cash sale at harvest.

Key Words: market efficiency, mean reversion, random walk, rollover hedging

JEL Classifications: Q13, G13

When agricultural commodity prices are unusually high, producers are tempted to try to lock in prices for several years of production at high levels. Some have argued that producers can capture the benefits of higher prices over an extended period of time by multiyear rollover hedging (Gardner; Kenyon and Beckman). Rollover hedging recommendations are sometimes made in the popular press and extension literature when crop prices are high. For example, *Farm Journal* economist Bob Utterback recommended the following strategy (Utterback, p. 7).

> The trigger for selling multiple years' crops is a close in the lead-month futures below the 18-day moving average; we'll buy September put options two strikes in the money. My plan is to price 100% of expected 1997 production when the trigger is tripped, and the '98 and '99 crops if the trigger occurs above $4. Then we'll convert the put options to futures when weather scares are past, and just keep rolling them forward.

The available empirical literature (Conley and Almonte-Alvarez; Gardner; Huang, Turner, and Houston; Kenyon and Beckman; Turner and Heboyan) has mostly found that rollover hedging increases mean returns but has used sample sizes that are too small to be conclusive and has not included significance tests. The literature has also given scant consideration to the connections between rollover hedging, the efficient market hypothesis, and the underlying stochastic process.

A survey of extension marketing economists found that a majority of extension economists did not disagree with the statement that rollover hedging can increase expected returns

Byung-Sam Yoon is an assistant professor at Chungbuk National University, Cheongju, Korea, and B. Wade Brorsen is a regents professor and Jean and Patsy Neustadt Chair, Department of Agricultural Economics, Oklahoma State University, Stillwater, OK.

(Brorsen and Anderson). Lence and Hayenga used a large sample size and found that it is infeasible for hedge-to-arrive contracts involving interyear rollover hedging to lock in high current prices for crops to be harvested one or more years in the future. Yet, their results still leave open the possibility of a small increase in returns.

Rollover hedging is different from standard hedging[1] in that it involves continuously switching from a nearby futures contract to a more distant futures contract. In rollover hedging, the hedger first opens a position in a nearby futures contract and later closes it while simultaneously opening the same position with a more distant futures contract. Interestingly, in the finance literature (e.g., Ross), rollover hedging is considered a way to lock in the long-run equilibrium value and is viewed solely as a means of reducing risk. Only in the agricultural economics literature is rollover hedging considered a way to increase mean returns.

For rollover hedging to increase expected returns, futures price movements should follow a mean reversion process in which price gradually moves toward its underlying fundamental value whenever it deviates from the underlying value. A mean reversion price process violates the efficient market hypothesis that is associated with the assertion that futures price changes are unpredictable. Cash prices[2] should be mean reverting as long-run adjustments in supply and demand force cash prices back to their long-term equilibrium (Dixit and Pindyck, pp. 74–78). In an efficient market, the mean reversion of cash prices would have been foreseen by futures traders, and there would be no mean reversion in individual futures contracts.

This study primarily aimed to determine whether rollover hedging could be used to increase mean returns for producers. Specifically, in this study, we determined whether futures prices are mean reverting in corn, soybean, and wheat markets by two different statistical tests. Futures prices must be mean reverting for rollover hedging to increase expected returns. In addition, simulations were conducted to provide additional evidence about whether rollover hedging could increase expected returns. Past simulation studies had too few observations to have any confidence in them. This study uses more commodities and longer time series than past research. Furthermore, although Irwin, Zulauf, and Jackson have examined mean reversion for a subset of the dataset used here, past studies have not included both mean reversion tests and simulation studies, which makes it difficult to determine whether differences in results are due to differences in techniques or differences in data.

Theories of Mean Reversion

Since Fama's discussion of efficient capital markets, the efficient market hypothesis (EMH) has become the dominant paradigm used by economists to understand and investigate the behavior of financial and commodity markets. The efficient market hypothesis holds that the market adjusts so quickly to new information that there exist no trading rules that consistently outperform the market in terms of expected returns. If there are inefficiencies, they are expected to be either too small or too short-lived to be exploited by investors. Thus, it is best for investors in the stock market to buy and hold a diversified market portfolio rather than attempt to time investments to beat the market.

However, in contrast to the efficient market hypothesis, a substantial number of anomalies in asset prices have been documented by financial researchers. Some have found mean reversion in asset prices and further suggested that asset prices are somewhat predictable. The literature explaining market inefficiencies and mean reversion in asset prices focuses on investor irrationality (noise) and temporary

[1] Another difference is that past agricultural economics research has advocated rollover hedging more as a speculative strategy than as a way to stabilize income, whereas hedging is usually promoted as a way to stabilize income by reducing price risk.

[2] Tests showed cash wheat prices were indeed mean reverting. The results are not presented here because cash prices are outside the focus of the article, and we did not have comparable data for the other commodities.

deviations of market price from its fundamental value. There is substantial evidence that people are not as rational as economists like to assume.

Biases of Judgment and Decision Making

Kahneman, Slovic, and Tversky and Kahneman and Riepe argue that there are many systematic errors of judgment and decision making that are relevant for investor behavior in financial and commodity markets.

First, investors tend to be overconfident or overoptimistic in their own abilities, which makes them bear more risk or attribute their investment success to skill rather than luck. Second, when only a few observations are available, investors tend to place too much weight on the available data and thus make erroneous inferences (fallacy of small numbers). Third, investors tend to think backward and consistently exaggerate what they knew in foresight (hindsight bias). They not only tend to view what has happened as having been inevitable, but also to view it as having appeared relatively inevitable before it happened. Thus, hindsight is an important element of investor overconfidence and a cause of regret (or myopic loss aversion). Fourth, investors put too little weight on background information and too much weight on new information in making inferences, which might lead them to overreact to news. Finally, investors tend to extrapolate recent trends into the future that are at odds with long-run averages and statistical odds, which can lead them to chase trends. Any trend that is inconsistent with market fundamentals will be temporary and prices will reverse toward their long-run mean.

Behavioral finance offers some theoretical support for mean reversion in futures prices. However, previous research on rollover hedging (Conley and Almonte-Alvarez; Gardner; Huang, Turner, and Houston; Kenyon and Beckman) can be tainted by the fallacy of small numbers or hindsight bias.

Overreaction or Overshooting

Using evidence from cognitive psychology, De Bondt and Thaler (1985, 1987) argue that the stock market systematically overreacts to news about fundamentals. Rausser and Walraven also argue that agricultural commodity markets overreact to a disturbance (e.g., droughts and other weather-related phenomena) and, therefore, prices of agricultural commodities overshoot their final equilibrium levels.

As a consequence of investor overreaction, asset prices can temporarily depart from their underlying fundamental values. When pricing errors from overreaction bias are eventually corrected, asset prices revert to their long-term mean. This investor overreaction hypothesis suggests that, on average, assets that have performed poorly (well) in one period will earn above-average (below-average) returns in the next period. Thus, a contrarian strategy of buying past losers and selling past winners should yield abnormal returns.

Fads or Speculative Bubbles

Shiller and Poterba and Summers argue that asset prices are heavily affected by fads or waves of optimistic or pessimistic market psychology. Similarly, Summers, West, and McQueen and Thorley explain anomalies in asset prices by a speculative bubble that is characterized by a long run-up in price (or a long run of many small positive abnormal returns) followed by a dramatic price drop or crash (relatively few large negative abnormal returns). The fads or speculative bubbles often drive the market price from its fundamental value and induce excess volatility. According to these explanations, mean reversion in asset prices occurs during the process in which transitory pricing errors induced by fads or speculative bubbles are corrected.

Time-Varying Risk Premium

For speculators who act as insurers to be induced to trade, they must be paid a risk premium as compensation for bearing the risks hedgers want to transfer. The risk premium equals the difference between the current futures price and the expected future spot price.

A common approach in past research used

to test for a risk premium is to test whether the intercept is zero and the slope is one in a regression of cash prices on futures prices. For corn and soybean, Kenyon, Jones, and McGuirk found that this hypothesis could not be rejected. Zulauf et al. updated their work and found one case in which soybean futures were found to be biased with the use of price-level data. In their percentage change regressions, they found no bias. Their percentage change model is likely the more appropriate model (Williams and Wright, p. 191). This set of work is testing a linear relationship and a constant risk premium, whereas rollover hedging hypothesizes a nonlinear relationship between cash and futures. But, such models likely still have some power to reject the null in the presence of the nonlinear model suggested by rollover hedging.

Hartzmark and Fama and French (1987, 1988) argue that because the amount of risk that speculators must bear varies through time, asset prices exhibit mean-reverting behavior. Kolb finds that futures markets for grains such as wheat, corn, and oats do not consistently exhibit a risk premium. McKenzie and Holt find a small risk premium during times of high uncertainty. A risk premium existing only during times of high prices has not been tested in past research. A time-varying risk premium provides another alternative explanation of why rollover hedging could be profitable.

Although the dominant theory is still efficient markets, there are alternative theories that can explain temporary deviations of asset prices from their equilibrium. In financial literature, judgment biases, investor overreaction, fads or bubbles, and time-varying risk premia are cited as a source of market inefficiencies. However, if such inefficiencies existed in the past, by making them known, the actions of traders could cause them to disappear, so there is a good reason to be cautious in recommending such strategies to farmers.

Data

The agricultural commodities chosen for the analysis of mean reversion in futures prices are corn, wheat, soybean, soybean oil, and soybean meal. Futures prices from the Chicago Board of Trade are obtained from the Annual Report of the Board of Trade of the City of Chicago and from a computer database compiled by Technical Tools, Inc. The sample period extends from January 1891 through December 1999 for corn and wheat, from January 1951 through December 1999 for soybean, and from January 1959 through December 1999 for soybean oil and soybean meal.[3] This is the longest set of futures price data ever used to study rollover hedging. A long data set increases the power of the statistical tests, but it increases the chances of structural change[4] occurring during the observation period.

To test for mean reversion in agricultural futures prices, return horizons of 1, 3, and 6 months are examined. For each return horizon, the beginning price and ending price are taken to calculate the k-month returns. The futures contract used to calculate the k-month returns is defined as the nearby futures contract that has enough days to maturity to cover the k-month period. The beginning price is the settlement price for a given futures contract on the first trading day of each calendar month, and the ending price is the closing price for the corresponding futures contract on the first trading day of the coming month with k-month interval. For example, constructing a 3-month return horizon for corn in January, the beginning price is the closing price of May futures observed on the first trading day in January,

[3] This study planned to extend the data period of each commodity to the launch date of each futures contract, but in early years after the introduction of futures contracts, the trading volume was extremely low and prices of only a few nearby contracts were irregularly reported. These years might be considered a learning period during which markets learn how to price new contracts; thus, they were excluded from the price series. The launch dates of futures contracts are as follows: corn and wheat, January 2, 1877; soybean, October 5, 1936; soybean oil, July 17, 1950; and soybean meal, August 19, 1951.

[4] Structural change tests were conducted for the variance ratio tests by splitting the sample into two equal sizes. In all cases, there was no rejection of the random walk null with either subsample, which is the same finding as for the entire dataset, except for corn with a 1-month horizon.

and the ending price is the closing price for the same May futures contract observed on the first trading day in April. The k-month returns are defined as the natural logarithmic difference between the beginning price and the ending price of the k-month horizon.

To test for mean reversion, the underlying mean value of the commodities must be estimated. In this study, 5-year moving averages are used to estimate the mean value of each commodity. The futures prices used to calculate the 5-year moving averages are closing prices for the futures contract nearest to maturity on the first trading day of each calendar month. For example, the 5-year moving average for January 1999 is the sum of the nearby closing futures prices on the first trading day of each month from January 1994 through December 1998 divided by 60.

Procedures

This study uses two statistical tests—the return predictability test and the variance ratio test—to test for the existence of mean reversion in agricultural futures prices and also conducts simulations to determine whether a multiyear rollover hedge can increase the hedger's average returns compared with marketing alternatives.

Return Predictability Test

The return predictability test examines whether the deviation of current market prices from estimates of underlying mean value can help predict returns over various horizons (Cutler, Poterba, and Summers; Irwin, Zulauf, and Jackson). We study returns over different horizons by estimating

$$(1) \quad (\ln P_{t+k} - \ln P_t) = \alpha_k + \beta_k(\ln M_t - \ln P_t) + \varepsilon_{t+k},$$

where P_{t+k} is the futures price at the end of the return horizon, P_t is the futures price at the beginning of the return horizon, and M_t is an estimated mean value at the beginning of the return horizon. The logarithmic price-relative $\ln P_{t+k} - \ln P_t$ is the continuously compounded return over k months.

The estimated coefficient β_k is the rate of mean reversion, meaning the fraction of the price deviation from the underlying mean value that is adjusted over a k-month horizon. For example, if the current price is 1% below (above) the mean value, then returns will be increased (decreased) by 0.01β over the next k months. A finding that β_k is significantly greater than zero is evidence in favor of a mean reversion process.

Overlapping sample periods are used. Ordinary least squares can produce consistent parameter estimates in this case, but the usual standard errors estimated are biased because of serial correlation in the error terms (Harri and Brorsen). In this study, the standard errors of regression coefficients are bias-adjusted by the Newey-West correction method (Newey and West). The Newey-West method is consistent but tends to underestimate standard errors in small samples. It is possible to correct the standard errors with Monte Carlo methods, but there is no need to here because the null hypothesis is not rejected even with standard errors that are underestimated.

One possible criticism of the return predictability test is that Equation (1) specifies a constant parameter process. The way rollover hedging strategies are implemented assumes mean reversion only occurs once prices pass a certain threshold. Slope dummies were inserted in Equation (1) on the basis of how far the futures price was away from the estimated mean. Such a model is a form of the threshold autoregressive model (see Campbell, Lo, and MacKinlay, p. 472, for a definition of threshold autoregressive models). In no case was the slope dummy significant, so the model in Equation (1) was used.

Variance Ratio Test

The variance ratio test uses the fact that if the natural logarithm of a price series P_t follows a random walk process, then the variance of k-period returns should equal k times the variance of one-period returns (Cochrane; Kim, Nelson, and Startz; Lo and MacKinlay; Poterba and Summers). The general k-period variance ratio statistic VR(k) is defined as

$$(2)\quad \mathrm{VR}(k) = \frac{\mathrm{Var}[r_t(k)]}{k\,\mathrm{Var}[r_t(1)]} = \frac{\sigma^2(k)}{k\sigma^2(1)} = 1 + 2\sum_{t=1}^{k-1}\left(1 - \frac{t}{k}\right)\rho(t),$$

where $r_t(k) = r_t + r_{t-1} + \cdots + r_{t-k+1}$; that is, k-period continuously compounded return $r_t(1)$ is a one-period return, and $\rho(t)$ is the tth-order autocorrelation coefficient of return series r_t. Equation (2) shows that VR(k) is a particular linear combination of the first $t - 1$ autocorrelation coefficients of return series r_t with linearly declining weights.

Lo and MacKinlay show that the variance ratio estimator can be calculated as

$$(3)\quad \sigma^2(k) = \frac{1}{m}\sum_{t=k}^{nk}(P_t - P_{t-k} - k\hat{\mu})^2,$$

where

$$m = k(nk - k + 1)\left(1 - \frac{k}{nk}\right) \quad \text{and}$$

$$(4)\quad \sigma^2(1) = \frac{1}{(nk - 1)}\sum_{t=1}^{nk}(P_t - P_{t-1} - \hat{\mu}),$$

in which

$$\hat{\mu} = \frac{1}{nk}\sum_{t=1}^{nk}(P_t - P_{t-1}) = \frac{1}{nk}(P_{nk} - P_0),$$

where P_0 and P_{nk} are the first and last observation of the price series. Lo and MacKinlay derive test statistics under both homoscedasticity and heteroscedasticity. Because futures returns have been shown to exhibit conditional heteroscedasticity (Yang and Brorsen), the asymptotic variance of the variance ratio, $\psi(k)$, is computed under heteroscedasticity.

The standard Z test statistic, $Z(k)$, is

$$(5)\quad Z(k) = \frac{\mathrm{VR}(k) - 1}{[\psi(k)]^{1/2}} \overset{a}{\rightarrow} N(0, 1),$$

where $\overset{a}{\rightarrow}$ indicates that the standardized test statistic is asymptotically normally distributed. A variance ratio equal to one implies that the futures price follows a random walk process, whereas a variance ratio of less than one implies a mean reversion process. The variance ratio rank tests of Wright were also considered because they are robust to conditional heteroscedasticity and nonnormality. Because the tests of Wright were all statistically insignificant, they are not reported here.

Simulations

Testing the returns obtained by simulated trading strategies is a more direct test of the effectiveness of rollover hedging than statistical tests. The disadvantage of simulations is that few signals might be generated, so tests might have low power. Therefore, the simulations could be the least useful of the three tests.

A basic assumption in the multiyear rollover hedge is that unusually high prices occur infrequently and that when they occur, hedgers should lock in these favorable prices for several years of production. To identify unusually favorable prices, the cumulative frequency distribution of the past 60 months (or 5 years) of futures prices is used. The futures prices used to calculate the 5-year moving frequency distribution of historical prices are closing prices for the new crop futures contract observed on the first trading day of each calendar month. Specifically, December futures prices for corn, July futures prices for wheat, and November futures prices for soybean are used to construct the frequency distribution. The futures price series extends over the period 1948–1999 for corn and wheat and 1958–1999 for soybean. Before the first year of the sample periods, only old crop futures contracts were reported for early months of the year. Therefore, we couldn't go back farther in time to construct the frequency distribution with new crop futures prices. At the beginning of each month, the frequency distribution of the historical futures prices is updated by adding the price of the most recent month and deleting the most distant month's price, thus keeping a constant sample size of 60 observations.

In this study, the trigger price level to enter into a rollover hedge is set at the upper 10%

of the frequency distribution.[5] Three-year rollover hedging periods are used. The marketing alternatives considered are routine annual hedges and cash sale at harvest. No consideration is made of possible tax consequences, which could be a major disadvantage of rollover hedging.[6]

In choosing a method of rolling over futures contracts, the first decision to be made is the selection of contract months involved in rollovers. The previous studies (Conley and Almonte-Alvarez; Gardner; Huang, Turner, and Houston; Kenyon and Beckman) simply chose to roll over from the maturing new crop futures contract to the next new crop futures contract. For example, the December 1994 corn futures contract was switched to a December 1995 corn futures contract at harvest time in 1994.

In this study, two different rollover methods are used. The first method is to continuously roll over from the maturing contract to the subsequent contract with the use of every contract month ("continuous rollovers"). For example, a 3-year rollover hedge for corn is initiated with the December contract of the first year, and when the December contract matures, it is rolled into the March contract of the second year, and then the maturing March contract is rolled into the subsequent contract. This process of rolling over contracts is continued until the rollover hedge is finally lifted.

The second method is to roll over from the maturing new crop futures contract to the next new crop contract in the following year, as done in previous studies, but includes one intermediate contract month to serve as a bridge between the new crop futures contracts ("bridged rollovers"). Specifically, May futures contract for corn and soybean, and December futures contract for wheat are used as bridge contracts. Thus, for example, the maturing December futures contract for corn of the first year is rolled into the May contract of the second year, and when the May contract matures, it is rolled into the December contract of the second year, and so on.

The second decision to be made in the method of rolling over contracts is the selection of a point in time to roll over (i.e., when to switch from the maturing contract to the next contract). Ma, Mercer, and Walker suggest that the use of first notice days as rollover dates is a logical choice for most purposes, as well as a popular choice for trading purposes. This study also uses the first notice day (i.e., the last business day of the month preceding the delivery month) as the rollover date to switch contracts and terminal dates to lift the hedge. The 3-year rollover hedging rules used in the study are summarized as follows.

First, the producer is assumed to produce 5,000 bushels or one contract of corn, wheat, or soybean each year. At the beginning of each calendar month, if a price equal to or exceeding the trigger price level is observed, the hedger will sell three contracts to execute a 3-year rollover hedge. Once a 3-year rollover hedge is executed in any year, no new additional positions are taken with other price signals within the same year because the 5,000 bushels of crop for each year are already priced. However, even when a rollover hedge is already in place for the production of the year, the hedger will sell additional contracts for the expected crop in the following years to a total of three contracts. For example, assume that a 3-year rollover hedge is initiated for corn in May 1995. The producer would sell three December 1995 contracts. Even if another price above the trigger price level is observed in July 1995, the producer is not allowed to sell additional contracts. However, if a new price exceeding the trigger price level is observed in June 1996, the producer will sell one contract for the expected 1998 crop,

---

[5] This study has also simulated the same trading strategies at the trigger price levels of 5% and 15% of the frequency distribution. Such simulations yielded essentially the same results as the simulation at the 10% trigger price level.

[6] Purcell (p. 56) argued, "there are no clear court rulings on what is and is not hedging." But, rollover hedging might fail to meet the "equal and opposite" test and it could also be classified as speculative (and thus subject to loss limitations) because rollover hedging as studied here has a profit motivation. Therefore, a producer could go ahead and treat rollover hedging as hedging for tax purposes, but if audited, they risk having their losses subjected to loss limitations.

besides the 1996 and 1997 crops already priced in May 1995.

Second, at rollover dates, the hedger will roll forward to the next contract month by simultaneously closing the positions on all contracts and opening new positions on the remaining unhedged long-term production.

Trading futures contracts incurs transaction costs, which include brokerage fees and liquidity costs. It is assumed that brokerage fees are \$50 for a round-turn trade (i.e., buying and selling) of a 5,000-bushel futures contract. Liquidity costs are payments earned by floor traders for the services of filling an order immediately at the market price. They are incurred each time a futures contract is traded. Liquidity costs for the grain futures market is estimated to be one price tick (¼ cent per bushel) for the more heavily traded nearby contracts and two price ticks for the more lightly traded contracts that are more than 5 months from delivery (Brorsen; Thompson and Waller). With the two components combined, transaction costs are at least \$75 (or 1.5 cents per bushel) for a round-turn futures trade.

The expected returns from the 3-year rollover hedge can be calculated for each year separately. Denote the initial futures price at which a 3-year rollover hedge is placed as F_i and assume that crop size for each year is equal to one contract. Then, the producer's revenue for the first year is given by

$$(6)\qquad R_1 = F_i + B_1 - C,$$

where B_1 is the contemporaneous cash-futures basis at the time the cash sale is made in the first year, and C is the futures transaction costs. For corn, B_1 is the difference between the producer's cash price and the December futures price on the first notice date of the December contract in the first year.

The revenue for the second year is

$$(7)\qquad R_2 = F_i + \sum_{k=1}^{N} S_k + B_2 - (N + 1)C,$$

where S_k is the spread between the maturing futures contract and the next futures contract at a rollover date, B_2 is the contemporaneous cash-futures basis in the second year, N is the number of rollovers, and C is the futures transaction costs. For example, when continuous rollovers are used for corn, there are five rollover spreads involved in one crop year (i.e., the December–March spread, the March–May spread, the May–July spread, the July–September spread, and the September–December spread).

Finally, the revenue for the third year is

$$(8)\qquad R_3 = F_i + \sum_{k=1}^{2N} S_k + B_3 - (2N + 1)C,$$

where B_3 is the contemporaneous cash-futures basis in the third year.

Generalizing to an n-year rollover hedge for any commodity, the revenue in year t can be written as

$$(9)\qquad R_t = F_i + \sum_{k=1}^{(t-1)N} S_k + B_t - [(t - 1)N + 1]C,$$

where F_i is the initial futures price at which an n-year rollover hedge is placed, $\Sigma_{k=1}^{(t-1)N} S_k$ is the sum of spreads at rollovers, B_t is the contemporaneous cash-futures basis at the time the cash sale is made in year t, N is the number of rollovers in 1 crop year, and $[(t - 1)N + 1]C$ is the total futures transaction costs. The total revenue for the n-year rollover hedge is $\Sigma_{t=1}^{n} R_t$.

For routine annual hedges, the producer would hedge each year's crop by selling a new crop contract at or soon after planting. Specifically, December corn and November soybean contracts are sold on the first trading day of May, and July wheat contracts are sold on the first trading day of December. The annual hedges are also lifted on the first notice day of each new crop futures contract.

For cash sales at harvest, the producer will sell each year's crop when harvested at the harvest-time cash price. In this study, U.S. monthly average prices at harvest for each commodity are used. Specifically, November average prices for corn, October average prices for soybean, and June average prices for wheat are used because the first notice dates

Table 1. Results of Return Predictability Tests with the Use of Futures Prices

Commodity	Return Horizon (k months)	Data Period	No. of Observations	β_k	t-statistics	R^2
Corn	1	1891–1999	1,200	−0.02	−2.06*	0.01
	3	1891–1999	1,198	−0.04	−1.65	0.01
	6	1948–1999	618	0.06	1.23	0.01
Wheat	1	1891–1999	1,193	−0.00	−0.34	0.00
	3	1891–1999	1,191	−0.01	−0.24	0.00
	6	1948–1999	618	0.06	0.93	0.01
Soybean	1	1951–1999	526	0.02	0.81	0.00
	3	1951–1999	524	0.07	1.04	0.01
	6	1957–1999	509	0.07	0.88	0.01
Soybean Oil	1	1959–1999	431	−0.01	−0.26	0.00
	3	1959–1999	429	0.02	0.26	0.00
	6	1959–1999	426	0.08	0.80	0.01
Soybean Meal	1	1959–1999	431	0.02	0.56	0.00
	3	1959–1999	429	0.05	0.66	0.01
	6	1959–1999	426	0.06	0.56	0.00

Notes: The estimated regression equation is $(\ln P_{t+k} - \ln P_t) = \alpha_k + \beta_k (\ln M_t - \ln P_t) + \varepsilon_{t+k}$, where $(\ln P_{t+k} - \ln P_t)$ is the continuously compounded return in futures prices from month t to month $t + k$, and $(\ln M_t - \ln P_t)$ is the natural logarithmic difference between the estimated mean value on the first trading day of month t and the closing futures price on the first trading day of month t. The t-statistics are bias-corrected by the Newey–West procedure.
* Regression coefficients are statistically significant at the 5% level.

for the December corn futures contract, November soybean futures contract, and July wheat futures contract are the last business days in November, October, and June, respectively.

Results

The results of the return predictability test are presented in Table 1. The estimated β coefficients are not statistically significant at the 5% level, except for corn with a 1-month return horizon. But the negative β coefficient of −0.02 suggests mean aversion rather than mean reversion. Overall, the regression R^2 values are extremely low. The R^2 value represents the percentage of the observed change over the return horizon that is explained by the difference between the futures price and the mean value at the beginning of the return horizon. Thus, the deviation of the futures price from its estimated mean value explains, at most, 1.0% of the observed change in the futures price.

The variance ratio test results in Table 2 also find little evidence of mean reversion in futures prices. None of the variance ratios, VR(k), are significantly different from 1.0. Several of the variance ratios are greater than 1.0, which would indicate positive serial correlation (mean aversion) rather than mean reversion.

The results of simulations for corn, soybean, and wheat marketing strategies are reported in Table 3. The expected prices from the 3-year rollover hedges are higher than the expected prices from the routine annual hedges and cash sales at harvest across all three commodities. The 3-year rollover hedges are selective in that the producer only enters into a rollover hedge when current futures prices at the beginning of the month exceed a predetermined percentage level of the 5-year moving frequency distribution. However, the standard deviation of expected prices for the 3-year rollover hedges are much larger than the routine annual hedges and cash sales at harvest.

Table 2. Results of Variance Ratio Tests with the Use of the Nearby Futures Price Series

Commodity	Return Horizon (k months)	Data Period	No. of Observations	Variance Ratio [VR(k)]	Z-statistic
Corn	3	1891–1999	1,257	1.10	1.80
	6		1,254	1.12	1.38
Wheat	3	1891–1999	1,250	1.06	1.19
	6		1,247	1.03	0.39
Soybean	3	1951–1999	583	1.11	0.78
	6		580	1.04	−0.13
Soybean Oil	3	1959–1999	488	0.98	−0.17
	6		485	0.96	−0.26
Soybean Meal	3	1959–1999	488	1.09	0.70
	6		485	1.04	0.18

Notes: The variance ratio is $VR(k) = [\sigma^2(k)]/[k\sigma^2(1)]$, where $\sigma^2(k)$ is the variance of k-month returns and $\sigma^2(1)$ is the variance of 1-month returns. The null hypothesis is that $VR(k) = 1$, meaning that futures prices follow a random walk process. No ratio is statistically different from 1.0 at the 5% level.

The results for corn marketing strategies show that the expected prices for the 3-year rollover hedges with a bridge contract are higher than those that use every contract month continuously because continuous rollovers involve higher transaction costs. Routine annual hedges and cash sales at harvest have almost identical means and standard deviations of expected prices.

The results for soybean marketing strategies show that 3-year rollover hedges have the highest expected prices and also the largest standard deviations at all trigger price levels. The expected prices from the continuous rollover hedges are higher than the expected prices from the bridged rollover hedges, whereas the standard deviations of the bridged rollover hedges are larger than the standard deviations of the continuous rollover hedges. Thus, from the mean variance (EV) criterion, the continuous rollover hedges dominate the bridged rollover hedges.

The results for wheat marketing strategies show that cash sale at harvest has the lowest price and lowest standard deviation. The expected prices from the continuous rollover hedges are higher than the expected prices from the bridged rollover hedges in spite of higher transaction costs. This is mainly because of the larger gains in rollover spreads.

To determine whether the expected prices from the 3-year rollover hedges are equal to the expected prices from the marketing alternatives, paired difference tests are used. Paired difference tests use the pairwise differences (d_i) of the expected prices between two marketing strategies. The null hypothesis to be tested is that the mean of the paired differences of the expected prices from two marketing strategies is zero; in other words, the expected prices of the two marketing strategies are equal.

The results of the paired difference tests for corn, soybean, and wheat are presented in Table 4. The paired t-tests comparing the expected prices of the two marketing strategies are based on the following five pairs of strategies: (1) continuous rollover hedges versus routine annual hedges (CRH-RAH); (2) continuous rollover hedges versus cash sales at harvest (CRH-CSH); (3) bridged rollover hedges versus routine annual hedges (BRH-RAH); (4) bridged rollover hedges versus cash sales at harvest (BRH-CSH); and (5) routine annual hedges versus cash sale at harvest (RAH-CSH).

In Table 4, the t-ratios ranging from −0.03

Table 3. Expected Prices and Standard Deviations for 3-Year Rollover Hedges, Routine Annual Hedges, and Cash Sale at Harvest, 1948–1999

		3-Year Rollover Hedge									
		(1)	(2)	(3) Rollover Spread		(4) Transaction Cost		Expected Returns (1 + 2 + 3 + 4)			
Statistics	No. of Obser-vations	Initial Futures Price	Cash-Futures Basis	Continuous Rollovers	Bridged Rollovers	Continuous Rollovers	Bridged Rollovers	Continuous Rollovers	Bridged Rollovers	Routine Annual Hedges	Cash Sale at Harvest
Corn											
Mean	30	237.98	−23.53	10.78	7.87	−12.25	−5.80	212.97	216.51	195.93	196.16
SD		94.73	16.01	51.13	44.19	5.80	2.32	110.92	107.27	73.48	71.43
Soybeans											
Mean	32	572.40	−25.52	22.19	−12.95	−17.25	−6.00	551.81	527.93	495.17	494.72
SD		250.74	29.96	112.88	136.33	8.00	2.29	295.05	312.78	194.74	184.28
Wheat											
Mean	24	361.16	−9.99	25.95	10.33	−11.50	−5.50	365.62	356.00	327.70	306.38
SD		105.11	24.37	80.48	69.92	6.12	2.45	161.32	156.70	97.44	87.57

Notes: Continuous rollovers denote continuously rolling over from the maturing contract to the subsequent contract with every contract month; bridged rollovers denote rolling over from the maturing new crop futures contract to the next new crop contract, with one intermediate contract month that serves as a bridge between the new crop futures contracts.

Table 4. Results of Paired Difference Tests for 3-Year Rollover Hedges, Routine Annual Hedges, and Cash Sale at Harvest, 1948–1999

Statistics	No. of Observations	CRH-RAH	CRH-CSH	BRH-RAH	BRH-CSH	RAH-CSH
Corn						
Mean		17.04	16.81	20.58	20.35	−0.23
SD	30	81.55	100.39	76.05	95.40	49.73
t-Ratio		1.15	0.92	1.48	1.17	−0.03
Soybeans						
Mean		56.65	57.09	32.76	33.21	0.45
SD	32	186.08	229.00	228.10	272.89	109.35
t-Ratio		1.72	1.41	0.81	0.69	0.02
Wheat						
Mean		37.92	59.25	28.30	49.63	21.33
SD	24	150.16	158.38	158.61	161.31	62.56
t-Ratio		1.24	1.83	0.87	1.51	1.67

Notes: CRH-RAH denotes the paired difference of the expected price between the continuous rollover hedges and the routine annual hedges; CRH-CSH denotes the paired difference of the expected price between the continuous rollover hedges and the cash sales at harvest; BRH-RAH denotes the paired difference of the expected price between the bridged rollover hedges and the routine annual hedges; BRH-CSH denotes the paired difference of the expected price between the bridge rollover hedges and the cash sales at harvest; and RAH-CSH denotes the paired difference of the expected price between the routine annual hedges and the cash sale at harvest. The *t*-statistic is $t = (\bar{d} - 0)/\sqrt{s_D^2/n}$, where $\bar{d}$ is the average of the paired differences (d_i) of the expected prices between two marketing strategies, n is the number of paired differences, and $s_D^2 = [\Sigma_{i=1}^n d_i^2 - (1/n)(\Sigma_{i=1}^n d_i)^2]/n - 1)$.

to 1.83 indicate that all these pairs for each commodity are not statistically different[7] from each other at the 5% level. This implies that the expected prices from the 3-year rollover hedges are not different from the expected prices from the marketing alternatives across all commodities. The low power of the simulation approach, even with our extensive dataset, illustrates that even a \$0.50/bushel gain is not statistically significant. Although the returns to some of the rollover hedging strategies look enticing, they are not statistically significant. Thus, the simulation results are consistent with the results of the mean reversion tests.

[7] The hypothesis tests assume normality of the differences. On the basis of a Jarque-Bera test, the null hypothesis of normality was rejected for 2 of the 15 pairs. Because these are multiple comparisons, a joint test of normality was constructed with a parametric bootstrap and the maximum of 15 independent Jarque-Bera tests as the test statistic. The joint null hypothesis of normality could not be rejected.

Conclusions

Both market advisors and researchers have often suggested rollover hedging as a way to increase producer returns. This study determined whether rollover hedging could increase expected returns for producers. For rollover hedging to increase expected returns, futures prices must follow a mean-reverting process. To test for the existence of mean reversion in agricultural commodity prices, this study used a longer set of price data and a wider range of test procedures than past research. Although rollover hedging increasing mean returns is inconsistent with the efficient market hypothesis, there are psychological theories that offer some support for the profitability rollover hedging.

With both the return predictability test, which is based on long-horizon regression, and the variance ratio test, we found that mean reversion does not exist in futures prices for corn, wheat, soybean, soybean oil, and soybean meal. The findings on futures prices are consistent with the weak form of market efficiency suggested by Fama and with previous empirical work.

The simulated trading results for 3-year rollover hedges provided additional evidence that the expected returns to the rollover hedging strategies are not statistically different from the expected returns to routine annual hedges and cash sale at harvest. Because of the positive, but statistically insignificant, returns to the simulation strategies, the results might not be sufficient to put the issue of rollover hedging to rest.

On the basis of this research, we cannot recommend rollover hedging as a way to increase mean returns. The lack of statistical significance is found across three diverse tests.

[Received August 2002; Accepted July 2004.]

References

Brorsen, B.W. "Liquidity Costs and Scalping Costs in the Corn Futures Market." *Journal of Futures Markets* 9(June 1989):225–36.

Brorsen, B.W., and K.B. Anderson. "Agricultural Economics Research and Extension Marketing Programs: How Well Are They Integrated?" *Journal of Agribusiness* 17(1999):135–48.

Campbell, J.Y., A.W. Lo, and A.C. MacKinlay. *The Econometrics of Financial Markets.* Princeton, NJ: Princeton University Press, 1997.

Cochrane, J.H. "How Big Is the Random Walk in GNP?" *Journal of Political Economy* 96(1988): 893–920.

Conley, D.M., and J. Almonte-Alvarez. "Long-Term Hedging Analysis for Soybeans, 1973–95." Selected Paper presented at the American Agricultural Economics Association meeting in Salt Lake City, Utah, August 1998.

Cutler, D.M., J.M. Poterba, and L.H. Summers. "Speculative Dynamics." *Review of Economic Studies* 58(1991):529–46.

De Bondt, W.F.M., and R. Thaler. "Does the Stock Market Overreact?" *Journal of Finance* 40(July 1985):793–805.

———. "Further Evidence on Investor Overreaction and Stock Market Seasonality." *Journal of Finance* 42(July 1987):557–81.

Dixit, A.K., and R.S. Pindyck. *Investment under Uncertainty.* Princeton, NJ: Princeton University Press, 1994.

Fama, E.F. "Efficient Capital Markets: A Review of Theory and Empirical Work." *Journal of Finance* 25(1970):383–416.

Fama, E.F., and K.R. French. "Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage." *Journal of Business* 60(1987):55–73.

———. "Permanent and Temporary Components of Stock Prices." *Journal of Political Economy* 96(1988):246–73.

Gardner, B.L. "Rollover Hedging and Missing Long-Term Futures Markets." *American Journal of Agricultural Economics* 7(May 1989): 311–18.

Harri, A., and B.W. Brorsen. "The Overlapping Data Problem." Unpublished manuscript, Oklahoma State University, Stillwater, OK, 1998.

Hartzmark, M.L. "Returns to Individual Traders of Futures: Aggregate Results." *Journal of Political Economy* 95(December 1987):1292–1306.

Huang, B., S.C. Turner, and J.E. Houston. "Strategic Rollover Hedging." Unpublished manuscript, University of Georgia, Athens, GA, 1994.

Irwin, S.H., C.R. Zulauf, and T.E. Jackson. "Monte Carlo Analysis of Mean Reversion in Commodity Futures Prices." *American Journal of Agricultural Economics* 78(May 1996):387–99.

Kahneman, D., and M.W. Riepe. "Aspects of Investor Psychology." *Journal of Portfolio Management* 24(1998):52–65.

Kahneman, D., P. Slovic, and A. Tversky. *Judgment under Uncertainty: Heuristics and Biases.* Cambridge: Cambridge University Press, 1982.

Kenyon, D.E., and C.V. Beckman. "Multi-Year Pricing Strategies for Corn and Soybeans." *Journal of Futures Markets* 17(1997):909–34.

Kenyon, D., E. Jones, and A. McGuirk. "Forecasting Performance of Corn and Soybean Harvest Futures Contracts." *American Journal of Agricultural Economics* 75(1993):399–407.

Kim, M.J., C.R. Nelson, and R. Startz. "Mean Reversion in Stock Prices? A Reappraisal of the Empirical Evidence." *Review of Economic Studies* 58(1991):515–28.

Kolb, R.W. "Is Normal Backwardation Normal?" *Journal of Futures Markets* 12(1992):75–91.

Lence, S.H., and M.L. Hayenga. "Pitfalls of Multi-Year Rollover Hedges: The Case of Hedge-to-Arrive Contracts." *American Journal of Agricultural Economics* 83(2001):107–19.

Lo, A.W., and A.C. MacKinlay. "Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test." *Review of Financial Studies* 1(1988):41–66.

Ma, C.K., J.M. Mercer, and M.A. Walker. "Rolling Over Futures Contracts: A Note." *Journal of Futures Markets* 12(1992):203–17.

McKenzie, A., and M.T. Holt. "Market Efficiency in Agricultural Futures Markets." *Applied Economics* 34(2002):1519–32.

McQueen, G., and S. Thorley. "Bubbles, Stock Returns, and Duration Dependence." *Journal of Financial and Quantitative Analysis* 29(September 1994):379–401.

Newey, W.K., and K.D. West. "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55(1987):703–8.

Poterba, J.M., and L.H. Summers. "Mean Reversion in Stock Prices: Evidence and Implications." *Journal of Financial Economics* 22(1988):27–59.

Purcell, W.D. *Agricultural Futures and Options: Principles and Strategies.* New York: MacMillan Publishing Company, 1991.

Rausser, G.C., and N.A. Walraven. "Linkages among Commodity Futures Markets and Dynamic Welfare Analysis." *Review of Economics and Statistics* 72(November 1990):631–39.

Ross, S.A. "Hedging Long Run Commitments: Exercises in Incomplete Market Pricing." *Economic Notes by Banca Monte dei Paschi di Siena SpA* 26(1997):385–420.

Shiller, R.J. "The Use of Volatility Measures in Assessing Market Efficiency." *Journal of Finance* 36(May 1981):291–304.

Summers, L.H. "Does the Stock Market Rationally Reflect Fundamental Values?" *Journal of Finance* 41(July 1986):591–601.

Thompson, S.R., and M.L. Waller. "The Execution Cost of Trading in Commodity Markets." *Food Research Institute Studies* 10(1987):141–63.

Turner, S.C., and V. Heboyan. "Managing Risk in Cotton Production Using Strategic Rollover Hedging." Paper presented at the Southern Agricultural Economics Association annual meeting, Fort Worth, TX, January 2001.

Utterback, B. "Outlook." *Farm Journal* (February 1996):6–7.

West, K.D. "Bubbles, Fads and Stock Price Volatility Tests: A Partial Evaluation." *Journal of Finance* 43(July 1988):639–56.

Williams, J.C., and B.D. Wright. "Storage and Commodity Markets." Cambridge: Cambridge University Press, 1991.

Wright, J.H. "Alternative Variance-Ratio Tests Using Ranks and Signs." *Journal of Business and Economic Statistics* 18(2000):1–9.

Yang, S.-R., and B.W. Brorsen. "Nonlinear Dynamics of Daily Futures Prices: Conditional Heteroskedasticity or Chaos?" *The Journal of Futures Markets* 13(1993):175–91.

Zulauf, C.R., S.H. Irwin, J.E. Ropp, and A.J. Sberna. "A Reappraisal of the Forecasting Performance of Corn and Soybean New Crop Futures." *The Journal of Futures Markets* 19(1999):603–18.