Post-Harvest Grain Storing and Hedging with Efficient Futures

by

Terry L. Kastens and Kevin Dhuyvetter

Suggested citation format:

Kastens, T. L., and K. Dhuyvetter. 1999. "Post-Harvest Grain Storing and Hedging with Efficient Futures." Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL. [http://www.farmdoc.uiuc.edu/nccc134].

Post-harvest Grain Storing and Hedging with Efficient Futures

Terry L. Kastens and Kevin C. Dhuyvetter*

This study is a simulation that tests whether Kansas wheat, corn, milo (grain sorghum), and soybean producers could have used deferred futures plus historical basis cash price expectations to profitably guide post-harvest unhedged and hedged grain storage decisions from 1985 through 1997. The signaled storage decision is compared to a representative Kansas producer whose crop sales mimic average Kansas marketings each year. Twenty-three grain price locations are examined. The simulation resulted in a 11¢ per bushel annual increase in grain storage profits for wheat producers, 27¢ for soybeans, -17¢ for corn, and -20¢ for milo; but storage profit differences varied substantially across locations. Inferences for random Kansas cash price locations were generally robust to alternative assumptions about interest rates or storage costs, but sensitive to assumptions of model starting dates and basis specification. Hedging tended to decrease risk but not impact profitability. Few results were consistent across the numerous scenarios involving different crops, locations, and specifications for futures-plus-basis post-harvest grain storage signaling models; thus, this research does not reject cash market efficiency.

Introduction

In recent years the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Marketing Risk Management has contained a thread focusing on differences in research findings and extension teachings. Zulauf and Irwin report that routine and systematic marketing strategies offer little hope for returns above simply selling at harvest, suggesting decreased extension emphasis on grain marketing strategies. However, using 1964-89 data for Ohio corn, and following Working, they hint that marketing gains may accrue to producers who use futures prices as a source of information rather than as a trading medium. Specifically, using current basis and deferred futures, along with expected future basis, they find projected returns to storage are reasonable indicators of actual hedged storage returns.

If Zulauf and Irwin are right, it makes sense for producers to focus less on pre- or post-harvest price-picking and more on futures-based storage signals. However, if cash markets are efficient, positive economic returns to grain storage should not generally prevail. Of course, market efficiency is likely to be observed only at sufficiently aggregated levels and only from the perspective of average-cost participants. Management decisions, however, are made at disaggregated levels by managers with widely varying costs. Thus, although it is important to point out the fallacies of marketing strategies that depend on futures inefficiency for profits, it could be valuable to develop strategies that apply to less aggregated prices and producer-specific costs, and which *assume* futures efficiency. At those levels, inefficient markets might be

* The authors are assistant professor and associate professor, respectively, Department of Agricultural Economics, Kansas State University.

uncovered that could be exploited for profit, even for average cost producers.[1] Further, explicitly including storage costs in alternative marketing strategies should make them more useful for producers, who must sell their crops at some point.

This research is motivated by repeated producer questions regarding appropriate grain marketing strategies. It follows up on Zulauf and Irwin's suggestion of using futures and cash prices as indicators of storage returns and is structured to develop post-harvest grain marketing strategies that are useful to extension economists and grain producers. The specific objectives are (*a*) to test whether Kansas wheat, corn, milo (grain sorghum), and soybean producers could have used deferred futures plus historical basis cash price expectations to profitably guide post-harvest grain storage decisions over the last 13 years, and (*b*) to examine whether they would have been better off yet, in terms of profit or risk, if grain storage were supplemented with futures hedges. More specifically, would producers who had used futures based grain storage signals have been more profitable than a representative producer whose crop sales mimicked average Kansas marketings each year, and, would simultaneously implementing short futures hedges have improved the probability of projected storage returns bearing out? These questions are answered in a simulation of 1985-97 grain storage returns for multiple Kansas locations.

Background

Grain storage decisions depend intimately and intuitively on expected cash prices (e.g., Williams and Wright). Intuitively, if the cash price expectation, taken at time t, for some future time period $t+h$, is greater than the current cash price at time t plus interest and storage costs over time h, then a profit-maximizing grain producer would store grain. Conceptually, grain storage is viewed as an all-or-none decision: either it pays to store or it does not, which means producers would be expected to market a crop only once. However, Goodwin and Kastens found that Kansas producers market their crops more frequently than once, and suggested that fixed marketing costs, capital and cash flow constraints, and risk are some of the factors impacting marketing frequency.

Although the futures efficiency literature is large, with diverse procedural approaches taken and diverse conclusions, the evidence generally favors efficiency — especially for grain

---

[1] Economic profits can be viewed as merely arbitrage around long run equilibria. In the Grossman and Stiglitz sense, market efficiency cannot be rejected if expected arbitrage returns are exceeded by costs of acquiring the necessary information. Yet, persistently low cost, thus high profit, producers might consider a market that yields positive economic profits inefficient. Apparently, such producers' informational costs (required to remain high profit) do not exceed arbitrage gains. For that matter, even average cost producers can garner positive profits if local cash price disequilibria are uncovered. Of course, market efficiency is a continuum, ranging from efficient, in the theoretically pure economic sense, to inefficient in the business world sense. Extension economists focus on that end of the spectrum expected to most elevate understanding among their producer audience. This paper focuses on futures efficiency and cash market inefficiency based on the supposition that producers might be better off if they focused less on marketing strategies which depend on favorable futures price changes.

futures. Further, there is little evidence that futures, and especially grain futures, contain risk premia (Kolb 1992, 1996). Grain businesses regularly forward price based on deferred futures, and futures prices *are* price expectations (Eales et al.). Futures prices are inexpensive to obtain and are at least as accurate as commercial and public providers of price forecasts (Just and Rausser; Marines-Filho and Irwin; Kastens, Schroeder, and Plain). Adding historical basis to deferred futures prices provides a simple and reasonably accurate procedure for using futures prices to formulate cash price expectations (Kastens, Jones, and Schroeder), and simple crop basis projection methods are often as accurate as more complex ones (Dhuyvetter and Kastens). Given grain futures efficiency, accuracy, and ubiquity, and given the simplicity and accuracy of futures-plus-historical-basis cash price forecasts, using deferred futures plus historical basis as cash price expectations in grain storage returns models is appealing. Also, as long as futures prices and basis expectations are unbiased, resulting storage returns over time should not depend on actually taking the associated storage hedge futures positions. Nonetheless, considering both hedged and unhedged storage might reveal interesting risk-rewards tradeoffs. Further, in a Ohio corn storage study, Zulauf and Irwin found that hedged storage was more profitable than unhedged when using expected basis changes to guide storage decisions.

Because of such grain storage mechanics as grain handling and elevating, which tend to be one-time events, and monitoring and aerating, which tend to be ongoing events, grain storage costs can be characterized as the sum of fixed and variable cost components. For example, the Agricultural Market Advisory Service (AgMAS) Project (Jackson, Irwin, and Good), which examines pricing performance of market advisory services and relies on grain storage costs, applies a cost structure considered representative of commercial storage in the corn belt — a fixed storage cost of 13¢ per bushel for corn and soybeans from October 15 through December 31, and a 2¢ per bushel per month charge thereafter. Other studies have used only variable storage costs, either to represent reality or to impose simplicity (e.g., Heifner; Fackler and Livingston). For Kansas, commercial grain storage costs are characterized as variable-cost-only (USDA's *Summary of Offer Rates for Country Elevators*).

Opportunity, or interest, costs for stored grain are potentially complicated because reduced-interest grain storage loans have traditionally been available to producers through the Commodity Credit Corporation (CCC) of the U.S. Department of Agriculture, albeit typically for less than 100% of the market value of the grain stored. Further, how a producer uses the cash generated from grain sales (e.g., add to savings or pay off loans) will determine appropriate grain storage interest costs for that producer. The important point is that, to ensure reasonable inferences, when alternative producer behavior is posited across different storage cost scenarios, the scenarios should involve reasonable estimates of interest and storage costs.

Storage Simulation Procedure

This research relies on a simulation of grain storage decisions based on futures plus basis cash price forecasts that lead to expected storage returns across alternative storage cost scenarios. As with all simulations, understanding the underlying assumptions, decision rules, and data is crucial to judging validity of the process, meriting a careful description of these issues.

Grain Storage Rule or Model

In each week t, beginning at harvest (t=*harvest*), a grain producer looks ahead to all possible future weeks, $t+1 \ldots t+H$, where H is the maximum look-ahead horizon available, and calculates an expected return to storage for each week. An expected return for horizon h (i.e., week $t+h$) is calculated as: the expected selling price in week $t+h$ less the market price in week t (current price) less interest and storage costs accrued over h weeks (as used here, returns are *net* returns — net of costs). If any of the $t+1 \ldots t+H$ expected returns are positive, grain is stored from week t to week $t+1$. In that case, the producer steps ahead to week $t+1$, now labeling that week as t, and begins the expected storage returns calculations anew. On the other hand, if all $t+1 \ldots t+H$ expected returns are nonpositive, all grain is immediately sold (in week t), and the producer waits until the next harvest before again engaging in the look-ahead expected storage returns process. Note that there is nothing in the grain storage model that precludes storing grain beyond the crop year, thus simultaneously storing multiple harvests.[2] Nor is the basic storage model based on taking futures hedge positions.

Futures Hedging Rule or Model

Whenever futures hedges are considered in this study they are classical hedges, where some short futures position, or other, is held — for exactly as long as grain is stored. However, unlike the grain storage rule, where storage depends only on identifying some point in the future associated with expected positive storage returns, choosing *which* futures contract to hedge with depends on identifying that point in the future where expected positive storage returns are greatest. The contract that will be the nearby at that time is the one that is sold for the storage hedge. Each week that grain is stored, the search for maximum hedged storage returns begins anew. If the expected storage returns to some week for a contract other than the one already held are sufficiently greater (enough to cover transaction costs) than the expected returns to any of the weeks involving the contract already held, the futures position is rolled to the second contract.

Like the grain storage rule, the hedging rule depends only on expected basis and efficient futures. There is nothing in the rule that precludes being in one futures contract for awhile, moving to another, and then back to the same contract. The decision is guided by maximizing expected returns to storage each week grain is stored. When the storage rule no longer signals grain storage, futures hedges are also lifted, as no expected storage returns are positive then.

---

[2] Considering that most grain tends to leave producer hands in the months surrounding harvest, and the additional on farm storage capacity potentially required, it might not seem appropriate to consider storage across harvest years. However, Kansas elevator storage rates do not distinguish between harvest years, and grain can always be moved from farm to commercial storage preceding the next harvest. In fact, it is assumed to have to move there to be sold anyway. Thus, as long as storage costs are appropriately considered, and as long as it makes sense to rely on futures-based storage signals, there is little reason to disregard those signals merely because grain has already remained in storage for some arbitrary time period.

Benchmarks for Comparison

How shall the grain storage model be evaluated by researchers and potential users? One possibility is to test historically whether the model generated positive returns to storage. On average, was the model's harvest equivalent price (sale price less interest and storage costs) greater than the harvest price? That evaluation method has at least two problems. First, in small samples, average returns to storage are highly conditional on observed price patterns in individual years, so model evaluation is masked by underlying price movements. Second, storage returns are highly conditional on storage costs. Not "allowing" the benchmark (harvest sales) to capture returns to storage would bias the analysis in favor of the storage model for especially low cost storers. There, model evaluation is masked because grain markets are expected to yield profits to low cost grain storers, with or without the use of a model.

A second way for evaluating the grain storage model's success is to test storage returns when using the model against those of a representative grain marketer over the same time period. Producers typically market crops throughout the crop year (although disproportionate shares are marketed around harvest). This evaluation method answers the intuitively appealing question, Would marketing grain using this model have been more profitable than a typical producer during the period examined? Moreover, by assigning the representative marketer the same storage cost structure as a model user, this process should not give undo credit to the model if storage costs are assumed low.[3] While some comparisons are made with prices available at harvest, this research focuses on comparing model-based with representative storage returns.[4]

---

[3] It is probable that a producer with low (high) storage costs has a different pattern of marketings than the representative marketer, however, information to determine that is not available. Thus, the marketing pattern for the representative marketer is assumed to be the same regardless of cost structure.

[4] Using the representative returns framework should help determine whether observed storage returns when *following* the model are actually *due to* the model. Nonetheless, tests of rule-based marketing strategies in small samples are always plagued with low power, and more conclusive evidence always awaits more years of data. Other benchmarks might be considered. For example, AgMAS currently uses an average of forward cash contract prices for harvest time delivery before harvest and actual cash prices, adjusted for storage and interest, after harvest. The data to calculate these benchmarks were unavailable in this study. As will be described later, representative marketings depend on USDA-reported crop year marketings (through *Kansas Agricultural Statistics*). These values include forward contracted grain as well as cash sales, potentially introducing error when a period's observed cash price is assigned to marketings for that period. Assuming efficient futures and accurate basis projections would mitigate that error as more years are aggregated in an analysis, but, a small risk-adjustment bias would likely still exist (biasing the representative price downwards) — because forward contracting transfers risk to elevators. Nonetheless, using the representative benchmark seems more reasonable than other assumptions of time-distributed grain sales following harvest. For example, using equal sales per period would be inappropriate because there is little evidence producers market grain in that manner.

Expected Prices

Expected prices are deferred futures prices plus historical basis. Following Hauser, Garcia, and Tumblin; Jiang and Hayenga; and Kenyon and Kingsley; 3-year historical bases are generally used in the simulations, but the process is tested with an alternative that makes use of current basis information. Namely, the 3-year historical average basis (for the time of year being forecasted) is averaged with the current basis (at the time a forecast is made).

Marketing Year Start (Harvest)

A post-harvest returns to storage marketing study logically should begin around harvest each year. For this Kansas study, a reasonable starting point is the week at which 50% of the Kansas crop is harvested. However, some producers might begin post-harvest marketing early or late in the harvest, thus, weeks when 20% and 80% of harvest is complete are considered as well (Zulauf and Irwin found returns to routine storage were highest for a mid-harvest beginning). Except where the distinction is needed, the marketing year beginning point, which varies from year to year, is simply referred to as harvest.[5]

Representative Marketer and Representative Price

The representative marketer is one who, in each week of each year, markets that portion of his crop which equals the estimated portion of the total Kansas crop marketed by all producers in that week of that year. The representative price is the harvest equivalent (adjusted for storage and interest costs), marketings weighted price of the representative marketer.

Interest and Futures Transaction Charges

Two interest rates are considered in the simulations, a bank loan rate and a CCC loan rate reflecting the cost of funds when government commodity loans are taken. Because CCC loans are typically not for 100% of grain market value, charging CCC rates against market price tends to understate actual interest costs for government loan holders — especially in years of high market prices. Nonetheless, the goal is to make some allowance for alternative interest rates. The precise historical accuracy of interest rates used is not particularly relevant because model users and non-users are each charged the same interest rate. Returns to futures hedges and rolling from one contract to another based on projected returns to storage must account for futures transaction costs. This study assumes those costs to be 1.5¢/bu. ($75/trade) throughout.

---

[5] Although year-specific Kansas harvest dates are considered, location-specific harvest dates are not. It is assumed that the point-of-harvest data resolution used is adequate to allow practical generalizations. Furthermore, although the harvest date could impact whether or not grain storage is initiated, ongoing storage depends on projected returns to storage from *each* week following harvest.

Storage Costs

At harvest, grain is considered either sold or placed in storage. Farm and commercial storage are differentiated only by the storage costs. Commercial storage cost is simulated by assigning commercial storage rates throughout. According to USDA's *Summary of Offer Rates for Country Elevators*, annual commercial grain storage rates for 1987-98 averaged 2.6¢ per bushel expressed on a per month basis for each of wheat, corn, milo, and soybeans. Further, with standard deviations around 0.06¢ per bushel (on a per month basis), the rates were quite stable over the time period. Communication with several grain elevator operators confirmed that rate and further revealed that it is customary for Kansas elevators to have a 30 day grace period after grain is first delivered to an elevator (grain sold within 30 days has no storage charge but is charged 31 days of storage if sold on day 31). Consequently, the commercial storage rate simulated is 0.65¢ per bushel per week, with a 4 week grace period.

Because grain is assumed delivered to a commercial elevator at some point, and because grain would be stored commercially if that were less expensive than farm storage, simulated relevant farm storage rates should generally be less than or equal to commercial rates. To cover alternative cost structures, simulated farm storage rates used here contain fixed and variable components, in two basic farm storage rates. Farm storage rate #1 assumes a 9¢ fixed charge coupled with a 1.1¢ monthly charge. This is an arbitrary division of fixed and variable charges that equates to commercial rates at 6 months. Farms with this storage cost structure would be better off storing on farm than in commercial elevators as long as the grain was held for at least 6 months. But, short term on farm storage would have large penalties relative to commercial storage, which is as it should be if physically moving grain in and out of storage is costly.

At harvest, grain must be hauled somewhere. It seems reasonable that some farms would want to avoid hauling grain to commercial elevators during harvest in order to avoid the high opportunity cost of machinery and labor associated with long distances to elevators or long waiting to unload times at elevators. Also, some farms may expect gains associated with the marketing flexibility of on farm storage (e.g., truck bids, or bids from more than one elevator). Such situations can be represented with a fixed cost wedge between commercial and farm storage costs. Thus, farm storage rate #2 uses the same 1.1¢ monthly variable cost as rate #1, but assumes an arbitrary fixed cost of -9¢.[6] Farms with this storage cost structure have a high market incentive to store grain, much as they would have in the examples just given. Regardless of the farm storage rate considered, to simulate making room for the new crop, all grain stored past 11 months accrues storage costs at commercial rates.

---

[6] Because the representative marketer holds nearly 100% of his grain in storage as of the first week following harvest (when the fixed cost is assessed), the -9¢ benefits both the representative and the model follower who may have been induced (by the -9¢) to hold grain at least 1 week. If the -9¢ is insufficient to initiate storage for the model follower, causing him to sell at harvest, then he relinquishes that benefit, which is as it should be if he is relying on model based storage signals — even though the representative marketer still captures that gain. The intent is to capture meaningful storage cost structures with a minimum of alternative simulations.

Multiple Grain Sales

Because producers demonstrate multiple sales for each crop harvested, grain storage is not typically an all or nothing decision and modifications to the grain storage model should allow for that. Furthermore, a producer may not wish to commit all of a crop to one marketing rule. Functionally, that is like initiating the storage model from different vantage points following harvest. For example, for cash flow or other reasons, a grain marketer may choose to sell a portion of his crop at harvest (or even ahead of harvest) and not revisit the marketing task on the remainder until a later date. Here, we consider starting the model 8 weeks after harvest to capture this possibility. For each year, at the selected model starting date, grain that was already marketed by a representative marketer is also considered sold in the same manner by the model marketer. Thus, for the later model starting date, it is somewhat less likely that a model follower would receive a different average price than the representative marketer.

Data

The base data used here are Wednesday closing cash prices for Kansas markets from January 1982 through December 1998. Prices were available from 23 locations for wheat, 11 for corn, 17 for milo, and 13 for soybeans. Cash price data were collected in 4-week months, or 48-week years; 4th and 5th Wednesday prices were averaged and reported as one value in months with five Wednesdays (see Kastens, Jones, and Schroeder for additional data detail). Kansas City wheat, Chicago corn, and Chicago soybean nearby and deferred futures prices were collected in the same manner and matched to the cash prices. Consistent with elevator behavior, nearby contracts avoid delivery months (e.g., the May contract is the nearby in March, even though a March contract trades). Cash and nearby futures prices allowed construction of current and historical average nearby basis values (milo used corn futures). Three-year historical average bases and 3-year-average-averaged-with-nearby bases provided two alternative basis projections. Basis projections were added to deferred futures prices to give cash price expectations. Conditional upon the existence of observed deferred futures trading prices each week, cash price expectations, and potential hedge prices if relevant, were formulated up to 45 weeks ahead. Any grain in storage or open futures positions at the last week in December 1998 are considered sold and closed then.

Post harvest marketing years were constructed corresponding to harvest years 1985-97 (1982-84 data were used to initialize models; post 1998 harvest data were insufficient to consider the 1998 harvest). To determine which week should be used to begin the marketing year for each crop each year, USDA's weekly *Crop Progress Reports* were used to determine the week closest to 20%-, 50%-, and 80%-completion from 1985-97. The average, minimum, and maximum 50%-completion calendar weeks were: wheat 23.9, 23, 25; corn 36.6, 35, 38; milo 39.1, 37, 41; and soybeans 38.1, 37, 41. These averages correspond to the 4th week in June, the 1st week in October, the 3rd week in October, and the 2nd week in October, for wheat, corn, milo, and soybeans, respectively. On average, 20%- and 80%-completion dates were two weeks earlier and later, respectively, than the 50%-completion dates for corn, milo, and soybeans, and one week earlier and later for wheat.

Marketing year weekly marketing portions are needed to construct the representative price series, with a marketing year beginning the week of harvest and ending the week preceding harvest of the following year. Monthly Kansas crop marketings obtained from *Kansas Agricultural Statistics* apply to official 12-month crop years where wheat begins in June and corn, milo, and soybeans begin in September. Official crop years do not coincide exactly with this study's marketing years. Additionally, reported crop marketings do not distinguish old and new crop sales. Thus, some modification was required to develop the weekly marketings numbers underlying this study's representative price series.[7]

Annual average interest rates charged by banks on new non-real estate farm loans were collected from the Federal Reserve System (*Agricultural Finance Databook)* and assigned to weeks by calendar year. Monthly average CCC interest rates were obtained directly from USDA's *Commodity Credit Corporation's Interest Rate Charges* and assigned to weeks. CCC rates were unavailable for some months in 1995-97. The proportional month-to-month change in prime loan rates (from the electronic database of the Federal Reserve Bank of St. Louis) was used to construct a proxy for the CCC rate for each missing period. From 1985 through December 1998 the average annual interest rates were 8.46% and 6.48% for the bank and CCC rates, respectively.

Simulation Results

To explore the stability of the futures-based hedged and unhedged grain storage models tested, several simulation runs were performed. Marketing patterns (percent sold each week each year) for the benchmark representative marketer do not change across simulation runs, except when considering different marketing year starting dates (early, mid, and late, corresponding to 20%-, 50%-, and 80%-harvest completion dates). Nonetheless, the representative price typically does change across runs because interest rates and storage costs impact returns for both the representative marketer and the storage model. To provide sufficient depth to the exposition much of the results focus on the base run (e.g., all figures and tables 1 and 2). The base run assumes the marketing year begins at mid-harvest and the storage model begins the same week.

---

[7] As a first step in constructing the representative price series, reported Kansas crop marketings for only the first month of each official crop year were adjusted downwards — by the average marketings in the last month of 1982-97 official crop years — to reflect the fact that a portion of old crop tends to carry into the new crop year and is counted as marketings there. Next, these slightly modified (new-crop-only) official monthly marketing weights were assigned to weeks (the September weight to each week in September, and so on). Here, marketing year weeks that run past the end of the official crop year were assigned the same weights as those of the last month of the official crop year (e.g., the four September and two October weeks at the end of a typical milo marketing year were assigned the August weights). To ensure that this study's marketing year marketings-to-date were compatible with those of the new-crop-only official monthly series, "catch up" marketing was assumed at harvest. For example, the marketing weight for milo in the week of a typical harvest (3rd week of October) was actually the sum of the marketing weights for the four September weeks and the first three weeks of October. Finally, all weekly marketing weights were normalized to sum to one over the marketing year.

Three-year basis histories are used in cash price expectations, interest charges are based on bank (rather than CCC) interest rates, and storage charges are 2.6¢ per bushel per month (0.65¢/week), which is the commercial storage rate.[8]

To help visualize marketing patterns of the representative marketer, figures 1-4 show average weekly Kansas marketing year marketings aggregated by month for each crop using the marketings calculation procedures discussed earlier and the base run mid-harvest marketing year starting dates. The figures span more than 12 calendar months — because the marketing years typically involve all or part of 13 calendar months, and because harvest times vary from year to year. Marketings are highest around harvest, with substantially lower marketings over the last half of the marketing year.

To put the base models' results in perspective, figures 5-8 show the harvest equivalent prices for each crop by year and averaged across locations for: (a) the harvest price, or that obtained by someone marketing 100% of a year's crop at harvest; (b) the representative price, which is that obtained by a marketer whose sales and storage patterns each year mirror those of a typical Kansas producer that year (those represented in figures 1-4); (c) the unhedged model price, which is the price obtained by a marketer following the base model without hedging, and (d) the hedged model price. Although some years show substantial disparity among the four location-average prices (e.g., 1996 on corn and milo or 1987 on soybeans), the four prices for a crop do not appear dramatically different on average. Hedged and unhedged bars are especially close, presenting a graphical confirmation of futures market efficiency. On average, the base storage model for a crop appears reasonable and marketers should not be averse to following it over time. However, there appears to be no compelling reason to follow the model either.

Table 1 (wheat and corn) and table 2 (milo and soybeans) show the annual advantage to following the base storage model, either unhedged or hedged, over the representative marketer for various Kansas locations. All 23 locations for wheat had positive advantages for both unhedged and hedged models. Observing *at least* 23 of 23 locations where the model's gain was positive is highly improbable (see the >0 count pval. row) if model vs. representative superiority for each location can be thought of as a binomial, or coin-flipping, experiment. Thus, if inferences are to be made about a random, or typical, wheat location, the results suggest that the grain storage model is successful as a grain storage strategy, with or without hedging. But, for inferences about individual wheat locations, results are far less conclusive. Only 1 of 23 locations (Marysville) had average unhedged model gains statistically different from 0, as judged by a paired-t test across the 13 yearly observations (1985-97) of wheat price for each location. None of the locational average hedged model advantages for wheat was significantly different

[8] Basis projections from historical 3-year average bases were generally unbiased. That is, from June 1985 to December 1998 for wheat, the period covered by the simulations, the mean error (actual basis less projection at the time it was forecasted) was 0.23¢/bu. From October 1985 to December 1998, mean errors of basis projections for corn, milo, and soybeans were -2.1¢/bu., -0.48¢/bu., and -0.42¢/bu., respectively.

from 0. On average, across the 23 wheat locations, the model advantages were 1.0¢/bu. and 8.1¢/bu., for unhedged and hedged models, respectively.

Unhedged soybean results (right half of table 2) are similar to wheat, with 13 of 13 locations showing higher prices for the model than for the representative marketer, and an average price that is 27.7¢ per bushel higher for the model. Also, 9 of 13 locations had statistically greater unhedged model prices — which means that inferences apply to most individual soybean locations. On the other hand, hedged results were dramatically different. There, although 10 of 13 locations displayed positive average model gains, none was significantly different from 0. In general, the results broadly support using futures based cash price expectations as indicators of returns to storage for wheat and soybeans. But, neither wheat nor soybean results support the idea that projected storage returns must be hedged in order to bear out.

Results for corn (right half of table 1) and milo (left half of table 2) are dramatically different than for wheat and soybeans. The unhedged storage model's price was lower than the representative marketer's for all 11 corn locations and all 17 milo locations, and the hedged model price was lower for all 11 corn locations and 14 of 17 milo locations. The binomial experiment probabilities associated with this many locations showing negative model gains were quite low. But, as in wheat, many locational values were not significantly different from 0, making many location-specific inferences suspect.

Clearly, the storage model does not perform well for corn and milo relative to wheat and soybeans, although hedging tended to mitigate the corn and milo storage losses. In general, the Storage Time columns of tables 1 and 2 show that the storage model stores corn and milo longer than wheat and soybeans. Although not shown, the storage model generally signaled storing corn and milo for many weeks following the 1996 and 1997 harvests — in spite of generally falling futures prices during those time periods. Moreover, December 1998 found both 1996 and 1997 corn crops still in storage for a number of locations. Because of falling prices during those time periods, the hedged model tended to keep net storage returns from being a complete disaster. For example, for corn harvested in 1996 in Colby, Kansas, which was still in storage and presumed sold at the end of 1998, the unhedged model price was only $0.59/bu. and the hedged price was $1.12. However, neither price was attractive compared to the representative price of $2.37 or the harvest price of $2.72. Such low model-based prices call to question whether producers would actually have the courage to stay with such marketing strategies even if they were believed to be successful in the long run.

Tables 1 and 2 showed base run results by location and reported the probability of drawing *at least* (*at most*) the observed number of positive values where that number was >= (<) half the total number of locations in a binomial experiment. Results were also examined by year, and years were counted (out of 13) where the model was superior on average across locations. Although that analysis generally confirmed results in tables 1 and 2, the model advantage for wheat and soybeans over corn and milo was not as pronounced. For wheat, in 9 of 13 years the unhedged model's gain was positive and in 11 of 13 years the model's gain was statistically different from 0. The pvalue associated with the *at least* 9 out of 13 count is 0.13. Greater-than-0 year counts, statistically-different-from-0 year counts, and associated pvalues for the other crops are corn 7, 7, 0.50 (*at least* 7 out of 13); milo 5, 10, 0.29 (*at most* 5 out of 13); and soybeans 11, 9, 0.01 (*at least* 11 out of 13).

Besides showing gains (over the representative marketer) in profitability associated with the unhedged and hedged storage model, tables 1 and 2 also depict the risk reduction associated with hedged over unhedged grain storage — in terms of percent reduction in variance of 13 annual model prices. Once again, corn and milo behave much differently than wheat and soybeans. On average, across the pricing locations, hedged storage reduced risk 20.2% and 23.3% over unhedged storage for corn and milo, respectively. On the other hand, risk was increased 1.4% and 34.0% for wheat and soybeans. That hedging had kept 1996 and 1997 corn and milo storage losses from being as large as they would have been without hedging also meant that price variance was smaller with hedging. Hedge-induced risk reduction was highly variable across locations for all crops. None of the locational changes in variance were significantly different from 0 based on a two-tailed F-test at 0.10 significance.

Statistically significant locational values in tables 1 and 2 suggest locational market inefficiencies that might be exploited for profit. But, the question remains, Are these equilibria departures actually systematic, thus repeatable? Or, are the statistically significant historical runs merely random events in a bigger picture? Had the analysis ended with soybeans, where many locations had positive and significant unhedged storage model profits, it would be tempting to extol the virtues of a well-conceived, efficient-futures, less-efficient-cash, storage signal framework. The immediate inference would be that soybean producers could profit from following the storage model at certain locations. However, no soybean locations had significant hedged model advantages, suggesting that large unhedged soybean advantages may have been accidental rather than due to some well thought out storage model. Further, the negative model advantages for corn and milo would likely further diminish confidence in the soybean storage model's future success. For example, a Hutchinson, Pratt, or Scott City soybean and corn producer would likely question the expected advantage to following the storage model for soybeans, which had positive and significant historical advantages, when both unhedged and hedged storage model advantages for corn are negative and significant in these locations. Clearly, given storage model disparities across crops, more in depth, crop-specific information is needed to induce marketing economists or producers to follow or not follow the storage models — which is beyond the scope of this study. Alternatively, with additional years of data, such disparities might disappear. As is often the case in economic analyses, these results point to the difficulty of combining statistical significance and economic theory into meaningful generalizations.

Tables 1 and 2 offer few marketing strategy recommendations that can be made with confidence across all crops (no locational geographical patterns emerged either). Following the unhedged storage model seemed profitable for wheat and soybeans but not for corn and milo. Hedging appeared to reduce profitability (over not hedging) for wheat and soybeans, but increase it for corn and milo. Hedging appeared to reduce risk for corn and milo, but increase it for wheat and soybeans. One consistency that did emerge across all crops is that the price received with hedged storage was closer to that received by the representative marketer than the price received with unhedged storage.

How sensitive was the grain storage model to different assumptions for basis projections, marketing year starting dates, model starting dates, interest rates, and storage rates? Table 3 reports these results for wheat and corn and table 4 for milo and soybeans. For reference, the Base Run column in table 3 (table 4) reports the identical information reported at the bottom of table 1 (table 2). Each subsequent column, beginning with Different Basis and ending with Farm Store #2, shows results for a different simulation. Only selected departures from the base model will be noted in the discussion around tables 3 and 4, which follows immediately. As with tables 1 and 2, few results are statistically important and inferences are highly suspect.

Using an average of 3-year historical basis and current basis rather than only the 3-year historical basis (the Different Basis column) resulted in decreased risk with hedging for wheat. Now, 19 of 23 locations had risk reduced with hedging, compared to only 10 locations in the base wheat model. Also, with the alternative basis specification, the hedged risk advantage was greater for soybeans and milo, but not for corn. The hedged model advantage rose substantially for milo with the new basis specification. Now, 16 of 17 milo locations had positive gains to the hedged model, compared to only 3 of 17 in the Base Run.

The Harvest Early and Harvest Late columns depict marketing year initiations at 20% and 80% harvest completion, respectively. Zulauf and Irwin found larger returns to *routine* storage if initiated at mid-harvest. In this study, mid-harvest *signaled* unhedged storage returns were smaller for wheat, corn, and milo, but larger for soybeans (compare Harvest Early to Base Run). With soybeans, the average increase in risk due to hedging appeared much greater with early harvest compared to mid-harvest (Hedged risk advantage went from -34% to -62%). Still, for early harvest, only one soybean location had a statistically significant change in risk due to hedging.

Starting the model late (Late Model Start: 8 weeks after mid-harvest) resulted in a reduced unhedged model advantage for wheat (-0.6¢ compared with 11¢ in the Base Run). Now, only 9 (compared to 23 in the Base Run) locations had positive unhedged model advantages in wheat. Generally, across all crops and except for hedged model advantage in soybeans, both unhedged and hedged model advantages diminished when the storage model was started 8 weeks after harvest.

Among the various simulations, Low Interest (CCC rates) appeared to induce the smallest changes relative to the Base Run in terms of model profitability or risk advantages — across all four crops. Not surprisingly, the lower interest rates did stimulate increased storage time across all crops.

The two on farm storage rates (Farm Store #1 and #2) did not appear to induce large changes relative to the Base Run in terms of profitability and risk. Farm Store #2, with a -9¢

fixed cost, had hedged model advantages within 1.5¢ of the Base Run for corn, milo, and soybeans, and within 4¢ for wheat. This was in spite of the fact that storage time tended to be substantially greater.

All in all, the simulation results in tables 3 and 4 were highly variable. For example, the temptation to recommend using either the unhedged or hedged storage model as a wheat marketing strategy quickly dissipates when viewing the results from starting the model 8 weeks after harvest. This is discouraging because there is little reason a basis-based storage signaling process should suddenly break down at a different model starting date. Similarly, a recommendation to use the storage model for soybean marketing appears to break down when grain storers simultaneously turn into hedgers. Even a temptation to discredit the storage model in milo tends to dissipate when current basis is used in basis projections, and coupled with hedging. Likely, what is needed in order to make reliable inferences, is many more years of data.

Consistent with futures efficiency, there was no clear advantage or disadvantage to hedging across the 32 storage model simulations (8 for each of 4 crops) in terms of profitability. That is, 17 of 32 showed that storage model profits increased with hedging over not hedging and 15 showed that profits decreased. In terms of risk, the results are somewhat more favorable for hedging, as risk fell with hedging in 20 of 32 simulations (the probability of at least 20 out of 32 is 0.11). As Zulauf and Irwin point out, hedged storage should reduce risk — cash and futures prices tend to move in the same direction; thus unhedged storage returns and short futures returns tend to move oppositely.

Interestingly, perhaps the most prevailing, yet seemingly anomalous, result across the 32 storage simulations is a perverse risk/reward relationship. In all but 3 simulations (Late Model Start and Low Interest for wheat, and Farm Store #1 for corn), whenever hedging reduced profits over not hedging, it increased risk, and whenever hedging increased profits it reduced risk. This seeming anomaly is not hard to explain. For example, hedged storage was more profitable than unhedged storage in situations when storage period futures prices fell. As already noted, because cash and futures prices move in the same direction, unhedged storage returns and short futures returns move oppositely. Thus, where hedging pays, it also mitigates unhedged storage losses, thereby reducing risk. Of course, with efficient futures, it is impossible to know which periods might be associated with profitable hedges. Thus, it is probably meaningless to discuss such conditional risk/reward tradeoffs.

Conclusion

Relevance is always an issue in agricultural economics. The less aggregated, the more comprehensive, and the simpler the underlying empirical process, the more likely results will be believed and the methods incorporated in producers' management decisions. This project sought to develop simple, post-harvest grain marketing strategies that depend only on futures price, historical localized basis, and producer-level storage costs, and which crucially assume futures efficiency. Cash price data from 23 Kansas locations were used in a grain storage decision simulation to test whether Kansas wheat, corn, milo, and soybean producers could have used deferred futures plus historical basis cash price expectations to profitably guide unhedged or hedged post-harvest grain storage decisions over the 13 harvests from 1985-97.

On average, a producer who had used deferred futures with 3-year historical basis and commercial storage rates to signal unhedged grain storage decisions would have improved profits by 11.0¢ per bushel per year for wheat and 27.1¢ for soybeans, but would have reduced profits by 17.4¢ and 19.7¢ for corn and milo, respectively, over the typical Kansas producer. Adding short futures hedges to signal-based grain storage changed conclusions especially for soybeans, where average profits fell from 27.1¢ to 2.1¢. These inconsistencies across crops and across hedging vs. not hedging demand additional crop-specific information or additional years of data before they instill much confidence. Also, benefits to using the signal-based grain storage procedure were highly variable across cash locations, which suggests that economists should be careful when making grain storage strategy recommendations to individual producers. Furthermore, for some crops and years the decision model would have stored grain for more than a year, obviously necessitating adequate equity or debt financing on the part of the model follower.

If inferences are confined to random rather than specific Kansas cash price locations, then the grain storage decision model was generally not sensitive to alternative interest rates or storage costs. It was sensitive to, but not clearly systematically related to, basis specification, harvest start date of the model, and whether the storage signaling process was allowed to begin at harvest or not until 8 weeks after harvest. Across all simulations considered, and consistent with futures efficiency, hedging did not typically change profitability. Hedging did, however, tend to reduce risk.

This research considered many scenarios across different crops, locations, and alternative specifications for futures-plus-basis post-harvest grain storage signaling models. What appeared to be a reliable finding based on statistical significance in one scenario was often reversed in another. Thus, based on this research, it would be inappropriate to suggest that post-harvest grain storage decisions should generally be based on projected returns to storage calculated from deferred futures plus historical basis. Consequently, based on this research, it would be inappropriate to reject cash market efficiency. Along with the wide data set used here, a longer data set would be helpful in making reliable inferences from studies such as these. Regardless, combining statistical significance and economic theory into meaningful generalizations about marketing strategies will always be difficult and should always proceed cautiously.

References

Agricultural Finance Databook. Board of Governors of the Federal Reserve System. Division of Research and Statistics, Washington, D.C. Several Issues.

Dhuyvetter, K.C. and T.L. Kastens. "Forecasting Crop Basis: Practical Alternatives." In *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, ed., T.C. Schroeder, pp. 49-67. Dep. Agr. Econ., Oklahoma State University, 1998.

Eales, J.S., B.K. Engle, R.J. Hauser, and S.R. Thompson. "Grain Price Expectations of Illinois Farmers and Grain Merchandisers." *Amer. J. Agr. Econ.* 72(1990):701-08.

Fackler, P.L., and M.J. Livingston. "Optimal On-Farm Storage." In *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, ed., B W. Brorsen, pp. 176-90. Dep. Agr. Econ., Oklahoma State University, 1997.

Federal Reserve Bank of St. Louis. Electronic Database at http://www.stls.frb.org/fred/.

Goodwin, B.K, and T.L. Kastens. "An Analysis of the Frequency of Marketing by Kansas Crop Producers." *Rev. Agr. Econ.* 18(September 1996):575-84.

Grossman, S.J., and J.E. Stiglitz. "The Impossibility of Informationally Efficient Markets." *Amer. Econ. Rev.* 70(June 1980):393-408.

Hauser, R.J., P. Garcia, and A.D. Tumblin. "Basis Expectations and Soybean Hedging Effectiveness." *N. Cent. J. Agri. Econ.* 12(January 1990):125-36.

Heifner, R.G. "The Gains from Basing Grain Storage Decisions on Cash-Futures Spreads." *J. Farm Econ.* 48(December 1966):1490-05.

Jackson, T.E., S.H. Irwin, and D.L. Good. "1996 Pricing Performance of Market Advisory Services for Corn and Soybeans." AgMAS Project Research Report 1997-02, December 1997. Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign.

Jiang, B. and M. Hayenga. "Corn and Soybean Basis Behavior and Forecasting: Fundamental and Alternative Approaches." In *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, ed. B. W. Brorsen, pp. 125-140. Dep. Agr. Econ., Oklahoma State University, 1997.

Just, R.E., and G.C. Rausser. "Commodity Price Forecasting with Large-Scale Econometric Models and the Futures Market." *Amer. J. Agr. Econ.* 63(1981):197-208.

Kansas Agricultural Statistics. U.S. Department of Agriculture. Topeka, Kansas.

Kastens, T.L., R. Jones, and T.C. Schroeder. "Futures-Based Price Forecasts for Agricultural Producers and Businesses." *J. Agr. Resour. Econ.* 23(July 1998):294-307.

Kastens, T.L., T.C. Schroeder, and R. Plain. "Evaluation of Extension and USDA Price and Production Forecasts." *J. Agr. and Resour. Econ.* 23(July 1998):244-61.

Kenyon, D.E. and S.E. Kingsley. "An Analysis of Anticipatory Short Hedging Using Predicted Harvest Basis." *S. J. Agri. Econ.* 5(1973):199-203.

Kolb, R.W. "Is Normal Backwardation Normal?" *J. Futures Mkts.* 12(1992):75-91

"The Systematic Risk of Futures Contracts." *J. Futures Mkts.* 16(1996):631-54.

Marines-Filho, J., and S.H. Irwin. "Pre-harvest Hedging Behavior and Market Timing Performance of Private Market Advisory Services." In *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, ed., B. W. Brorsen, pp. 275-305. Dep. Agr. Econ., Oklahoma State University, 1995.

U.S. Department of Agriculture. *Commodity Credit Corporation's Interest Rate Charges.* Farm Services Agency, Washington, D.C. Unpublished report, May 24, 1995.

U.S. Department of Agriculture. *Crop Progress Report.* National Agricultural Statistics. Several Issues, 1985-97.

U.S. Department of Agriculture. *Summary of Offer Rates for Country Elevators.* Farm Services Agency, Kansas City, Missouri. Unpublished report, February 24, 1998.

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

Working, H. "The Theory of the Price of Storage." *Amer. Econ. Rev.* 39(1949):1254-62.

Zulauf, C.R. and S.H. Irwin. "Market Efficiency and Marketing to Enhance Income of Crop Producers." *Rev. Agr. Econ.* 20(Fall/Winter 1998):308-31.