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Abstract

The study examines if a storage strategy based on the cash-futures basis (the basis strategy) has been profitable over the 1975-2012 crop years for Illinois corn and soybeans. The study first examines the means and standard deviations of annual net storage returns obtained from hedged and unhedged storage when routinely storing each year and when using the basis strategy. For both the period of higher commodity prices since 2005 and the pre-2006 period, the basis strategy is found to (1) improve net returns to hedged but not unhedged storage and (2) lower the return risk for both hedged and unhedged storage. Previous studies have not examined the basis strategy's impact on the return risk for unhedged storage. To further investigate the performance of the basis strategy in these two periods, the performance of the expected net return to storage in forecasting the observed net storage return is examined. Given the panel structure of the data, a Fixed Effects (FE) model was chosen to estimate since the region specific effects are of interest. However, significant cross-equation correlations are found in the disturbances, a characteristic not investigated in previous studies. Thus, a Fixed Effects (FE) Panel Seemingly Unrelated Regressions (PSUR) is estimated. Forecast performance of the observed net storage return by the expected net storage return was found to be unbiased in the pre-2006 period. Forecast performance deteriorated somewhat in the post-2006 period as some forecasts were found to be biased. The decline in forecast performance is consistent with the lack of convergence that has been noted in the soybean and especially corn futures markets during some of the years since 2006.

Key words: basis strategy, futures market, hedge, return to storage, return risk
JEL codes: G14, G17, Q11, Q13

INTRODUCTION

The ability to forecast returns to storage has been a subject of interest to economists because commodities that have a harvest must be stored to meet demand for the commodity until the next harvest. In 1953, Holbrook Working proposed a strategy, commonly referred to as the basis strategy, of storing only when the current futures-cash basis exceeds the cost of storage. Working argued that changes in the cash-futures basis are more predictable then changes in either cash or futures price. However, empirical studies provide a mixed picture of its effectiveness. Heifner (1966), Zulauf and Irwin (1998) and Siaplay et al. (2012) find support for the strategy while Kastens and Dhuyvetter (1999) do not find support. The first three studies have a longer observation period and use state-level data. In contrast, Kastens and Dhyyvetter use data from individual elevator locations.

Moreover, Irwin et al. (2008) noted, "market participants have expressed concern that futures prices have been artificially inflated since the Fall of 2006, contributing to weak and erratic basis levels and a lack of convergence of cash and futures prices during delivery." Convergence is considered an important factor in the effectiveness of futures as a hedging instrument, and thus also is important for the performance of the basis strategy. Furthermore, Taylor, Dhuyvetter, and Tonsor (2013) found that the variability of basis was higher since 2006 for Kansas wheat. They noted that higher basis volatility will make accurate basis forecasts more difficult. Both studies suggest that the basis storage strategy may have been less effective since the 2006 grain price run-up. However, to the authors' knowledge, no study has examined this issue.

This study adds to the literature on performance of the basis storage strategy by examining net storage returns using data for seven Illinois regions over the 1975-2012 crop years for corn and soybeans. This data set allows an investigation of the performance of the basis strategy since the grain price run-up. While not elevator specific data, the data are regional and thus less aggregated than state level data. The analysis also contributes to the literature by investigating the impact the basis strategy has on the return risk for unhedged storage, a topic neglected in the literature.

Also investigated is the performance of the expected net return to storage from the basis strategy in forecasting the observed net return to storage. Significant cross-equation correlation is found in the disturbances of the regression equations resulting from the panel nature of the data. This statistical characteristic has not been noted previously in the literature. Thus, to gain efficiency in estimation, a Fixed Effects (FE) Panel Seemingly Unrelated Regressions (PSUR) is estimated. The article ends with conclusions and implications.

RELATED LITERATURE

A key concept in the study of speculative prices is the Efficient Market Hypothesis (Fama, 1970). This concept states that an efficient market will completely and accurately incorporate all available, publicly known information at the time a price is determined. Given that grain futures markets are generally found to be efficient (Kastens and Schroeder, 1996; Tomek, 1997), it is not surprising that studies have found that futures prices are not a useful indicator of the returns to storage (Tomek, 1997; Siaplay et al., 2012). Moreover, predictions of cash price changes also have generally been found to be unreliable indicators of the returns to storage except that the average change in cash price over time must cover the average cost of storage in order for storage to occur (Working, 1953b; Tomek and Peterson, 2005; Reichsfeld and Roache, 2011).

However, Working (1953a) argued that the cash-futures basis, or difference between cash and futures prices, can guide profitable inventory control in agricultural commodities. He presented empirical evidence of a significant relationship between the initial cash-futures basis and actual gross return to subsequent hedged storage until the delivery month for Kansas City wheat (Working, 1953b). His data set spanned the 1922-1952 crop years. Because he was using data for a delivery point, he assumed that the basis during the delivery month was zero due to convergence of the cash and futures price. Based on his findings, Working proposed a strategy of storing only when the expected change in the cash-futures basis exceeded the cost of storing. This proposal has since become known as the basis strategy.

Since the seminal studies of Working, a number of economists have examined the basis strategy. Heifner (1966), using a linear regression for 1952-1965 Michigan corn prices, found that the initial cash-futures basis explains, on average[2], 74 percent of the variation in gross return to hedged storage but only 6 percent of the variation in gross return to storage that was not hedged, or unhedged storage. Based on the regression estimates and Monte Carlo simulations of net storage returns at different hypothesized levels of storage costs, Heifner concluded that the basis strategy generally improved net returns to hedged storage relative to routine[3] hedged storage. Heifner emphasized the necessity to investigate various storage periods by comparing the usefulness of the basis strategy for three different intervals, the interval immediately after harvest, the succeeding interval, and the remainder of the marketing year. He also argued, "Conditional storage rules which make use of price forecasts based upon cash-future spreads are potentially most useful during the second interval. Decisions in January and March about storing corn appear to be particularly important."

Distinctive from the Monte Carlo approach by Heifner (1966), Zulauf et al. (1998; also reported in Zulauf and Irwin, 1998) used moving averages of the previous 3 year's basis at the end of the storage period to forecast the future basis and thus to calculate the expected net return to storage. Using 1964-1997 data of Ohio corn prices, they found that the basis strategy increased net return to storage only when combined with a futures hedge. They also found that storage returns varied significantly by the initial storage date, with the greatest net return occurring at the 50% harvest completion date and the lowest net return occurring at the 10% harvest completion date. This finding accords closely with Heifner's suggestion to examine various storage periods. Zulauf et al. (1998) also graphically described that the basis strategy reduces the standard deviation of net storage returns for hedged storage, but did not investigate the impact on the return risk for unhedged storage.

In contrast, using a methodology similar to Zulauf et al. (1998), Kastens and Dhuyvetter (1999) found inconsistent return performance of the basis strategy for both hedged and unhedged storage under multiple scenarios across 23 Kansas locations and 4 Kansas crops. Their data were for 1985-1997. They concluded, "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."

A recent study by Siaplay et al. (2012) used regression analysis to examine if there is a profitable market signal that helps producers and elevators make storage decisions. They examined Oklahoma wheat prices from 1975 through 2005. They calculated the expected change in the basis using a moving average basis of the previous 5 years. They found that the basis strategy is a useful predictor for both hedged and unhedged storage, but its forecasting power is higher for hedged storage.

[2]The R^2 is averaged over regressions with different storage intervals.

[3]Routine storage is a strategy of storing every year.

Finally, Heifner (1966) reported the standard deviations of annual net returns to hedged storage with and without using the basis strategy, but did not discuss the risk performance of the basis strategy. Moreover, while many studies have focused on the risk reduction function of futures hedging, the authors could find no study that analyzed the risk performance of the basis strategy except for the graphical analysis by Zulauf et al. (1998).

METHODS

General Procedures

A farmer in Illinois is assumed to face a decision at harvest of whether to store or not store. The decision to store has two additional choices: (1) whether to hedge 100% with futures contracts or to store unhedged, and (2) whether to adopt the basis storage strategy or the routine storage strategy. Four storage strategies emerge from these two storage choices: routine hedged storage, routine unhedged storage, basis strategy hedged storage, and basis strategy unhedged storage.

Unhedged storage involves holding the harvested grain until the cash commodity is sold. Returns to unhedged storage depend only on changes in cash market prices. Hedged storage involves holding the commodity in storage along with a short futures position. Returns to hedged storage thus depend on relative changes in the cash and futures prices, or changes in the basis.

The basis strategy is to store only if the expected net return to hedged storage exceeds zero. The routine storage strategy is to store every year regardless of the level of expected return.

This study calculates storage returns obtained from the four different strategies at five different initial storage dates: three different harvest completion dates and two post-harvest dates. The three harvest dates are the 10 percent, 50 percent, and 90 percent harvest completion dates. The two post-harvest dates are the first weeks of January and April. Zulauf et al. (1998) found that net return to storage varied by time of harvest. Their explanation was that, on average, cash prices follow a "*j* shape" at harvest. They are high as harvest begins, then decline with increasing harvest pressure, bottoming later in harvest, and then beginning a rise to cover the cost of storage. Zulauf et al. used the average date[4] at which harvest reached a given completion rate. This study uses a year-specific harvest completion rate since the date varies substantially across the crop years. The two post-harvest dates were added as a sensitivity test to see how robust the basis strategy was at different dates.

The storage hedge is placed in the July futures contract at harvest. The hedge remains in place until the farmer closes out this position by buying back the July contract on the same day that the cash commodity is sold. The July contract is used because it is the last futures contract in the crop marketing year for corn. An August contract is traded for soybeans, but to be consistent with corn, the July futures contract is also used for soybeans. A September futures contract is traded for corn and soybeans, but it may trade as a new crop contract if soybean and corn harvest is early.

More complex storage strategies could be investigated. Storage hedges could be placed in futures contracts that mature earlier than the July contract. These include the March and May contracts for both corn and soybeans. The storage hedges could also be rolled from an earlier maturing contract to a later maturing contract until the cash corn or soybeans are sold. In addition, options could be used instead of futures as the hedging instrument. This study opted for a simple storage

[4]The average date was the first week of October, the first week of November and the last week of November for 10%, 50% and 90% harvest completion, respectively.

strategy because our interest is the base level returns to storage, not the potential to enhance returns to storage by adopting a more dynamic storage strategy.

The basis strategy is to store only if the gross return to storage is expected to at least equal the cost of storage. Storage costs include (1) physical storage cost or the cost to keep a commodity in useable condition; (2) insurance cost or the cost to cover physical destruction of the stored commodity; and (3) opportunity cost or the cost equal to the interest income that could be earned from selling the commodity instead of storing the commodity. Because the cost of insurance is small, it is not included in this study. This decision is consistent with previous studies.

Data

The futures settlement prices examined in this study are for Thursday, or Wednesday if Thursday falls on a holiday. Futures prices are the settlement price for the July futures contract on the Chicago Mercantile Exchange and obtained from Barchart.com. Cash prices are the price paid to Illinois farmers by country elevators and obtained from the U.S. Department of Agriculture (USDA) and Illinois Department of Agriculture. And, cash prices are available for seven[5] Illinois regions.

Interest rates used to calculate storage opportunity cost are the bank prime loan rate from the Federal Reserve Economic Data (FRED) maintained by the Federal Reserve Bank (FRB) of St. Louis. Physical storage costs are from the USDA, Commodity Credit Corporation (CCC) through the 2008 crop year. However, CCC changed the method used to report storage rates by commodity, resulting in a substantial increase in storage rates. Thus, for the more recent years, physical storage rates were collected from an Ohio country elevator and then cross checked with another Ohio elevator. This storage rate is more consistent with the storage rates reported by CCC for 2008 and earlier years.

The calculation of storage costs for hedged storage includes the brokerage fees and liquidity costs of trading the July futures contract. A brokerage fee of $50 is used for the round trip cost of buying and selling the futures contract. Liquidity cost arises because futures prices change and trades cannot be executed instantly. Thus, the price at which a futures trade is executed will likely differ from the price at which the trader authorized the trade. Liquidity cost is calculated as $25 per futures trade before February 1 and $12.50 thereafter. Liquidity cost[6] declines because trading volume increases as the July contract approaches maturity, reducing the difference between the execution and desired price.

Finally, harvest progress dates are obtained from the Weekly Weather and Crop Bulletin jointly published by USDA and the Departments of Commerce.

When either cash or futures price was missing for a Thursday or Wednesday during the storage year, then the week was eliminated from the analysis. If the cash or futures price was missing exactly at a initial storage date, then the expected net return to hedged storage (the basis signal) for that crop year could not be calculated, thus the entire crop year was eliminated from the analysis for the specific crop and initial storage date. For example, only a crop year (2011-2012) was eliminated for the corn storage initiated from 10% harvest, and no crop year was eliminated for the other storage periods for corn.

[5]The seven regions are Northern, Western, North Central, South Central, Wabash, West Southwestern, and Little Egypt of Illinois.

[6]For more information, see Brorsen (1989) and Thompson and Waller (1987).

Calculations of Net Storage Returns

The basis storage strategy is to store only if, at each initial storage date, the expected net return to hedged storage through the first week of July exceeds zero. Expected per bushel net return to hedged storage is calculated:

$$(1)\quad \mathrm{ER}_{i,\tau1,\tau2,t} = [\frac{1}{3}\sum_{k=1}^{3} b_i(\tau2, t-k) - b_i(\tau1, t)] - [\mathrm{P}(\tau1, \tau2, t) + \mathrm{I}_i(c_i, \tau1, \tau2, t) + \mathrm{BF}(t) + \mathrm{L}(t)]$$

where $\mathrm{ER}_{i,\tau1,\tau2,t}$ = expected net return to hedged storage using the expected change in basis for a storage period from $\tau1$ to $\tau2$ of crop year t for region i of the state of Illinois, $b_i(\tau, t) = c_i(\tau, t) - f(\tau, t)$ = cash-futures basis, $c_i(\tau, t)$ = cash price, $f(\tau, t)$ = futures price, $\frac{1}{3}\sum_{k=1}^{3} b_i(\tau2, t-k)$ = expected basis for the first week in July, $b_i(\tau1, t)$ = initial basis of July futures, P = per bushel physical storage cost, I_i = per bushel interest opportunity cost, BF = per bushel futures trade brokerage fee, and L = per bushel futures trade liquidity cost. In the study, there are five different $\tau1$'s; 10 percent, 50 percent, 90 percent harvest completion dates, the first week of January and the first week of April, while $\tau2$ is fixed at the first week of July for each crop year.

The per bushel interest opportunity cost (I_i) incurred by storage from $\tau1$ to $\tau2$ for crop year t and region i is calculated as:

$$(2)\quad \mathrm{I}_i(c_i, \tau1, \tau2, t) = c_i(\tau1, t) * \mathrm{IR}(\tau1, t) * \frac{[7 * (\tau2 - \tau1)]}{365}$$

where $\mathrm{IR}(\tau1, t)$ = interest rate (bank prime loan rate from FRED, FRB of St. Louis) at $\tau1$ of crop year t, and $(\tau2 - \tau1)$ = length of storage in weeks.

Equation (1) contains a term for predicted future basis ($b_i(\tau2, t)$). Accurate prediction of the future basis is critical since it is the only unknown variable in equation (1). Various forecasting techniques exist, including autoregressive moving average (ARMA), autoregressive integrated moving average (ARIMA), and vector autoregressive (VAR) models. However, the agricultural economics literature generally has used a moving average of the basis in prior years because of its simplicity and ease of calculation. Based on a review of this literature, three years was selected as the length of the moving average. Jiang and Hayenga (1998) found the three-year moving average to be a reasonably accurate basis forecast for U.S. corn and soybeans. Taylor, Dhuyvetter and Kastens (2004) recommended using a two-year historical average for Kansas corn, and a three-year historical average for Kansas soybeans. Hatchett, Brorsen, and Anderson (2010) found that the optimal length was less than four years for Illinois corn and soybeans, with no statistical difference in forecast errors for moving averages of less than four years. Zulauf et al. (1998) used the three-year moving average for Ohio corn due to its computational simplicity with acceptable accuracy.

The actual per bushel net storage return for each storage strategy is calculated as:

$$(3)\quad \mathrm{AR}^{\mathrm{RHS}}_{i,\tau1,\tau2,t} = [b_i(\tau2, t) - b_i(\tau1, t)] - [\mathrm{P}(\tau1, \tau2, t) + \mathrm{I}_i(c_i, \tau1, \tau2, t) + \mathrm{BF}(t) + \mathrm{L}(t)]$$

$$(4)\quad \mathrm{AR}^{\mathrm{RUS}}_{i,\tau1,\tau2,t} = [c_i(\tau2, t) - c_i(\tau1, t)] - [\mathrm{P}(\tau1, \tau2, t) + \mathrm{I}_i(c_i, \tau1, \tau2, t)]$$

$$(5)\quad \mathrm{AR}^{\mathrm{BSHS}}_{i,\tau1,\tau2,t} = \mathbb{1}_{[\mathrm{ER}_{i,\tau1,\tau2,t} > 0]} * \mathrm{AR}^{\mathrm{RHS}}_{i,\tau1,\tau2,t}$$

$$(6)\quad \mathrm{AR}^{\mathrm{BSUS}}_{i,\tau1,\tau2,t} = \mathbb{1}_{[\mathrm{ER}_{i,\tau1,\tau2,t} > 0]} * \mathrm{AR}^{\mathrm{RUS}}_{i,\tau1,\tau2,t}$$

where AR = actual return, RHS = routine hedged storage, RUS = routine unhedged storage, BSHS = basis strategy hedged storage, BSUS = basis strategy unhedged storage, and $\mathbb{1}_{[\mathrm{ER}_{i,\tau 1,\tau 2,t} > 0]}$ is an indicator function which is equal to 1 if $\mathrm{ER}_{i,\tau 1,\tau 2,t} > 0$, and zero, otherwise. To illustrate the interpretation of the right hand variables in equations (3)-(6), for example, $\mathrm{AR}^{\mathrm{RHS}}_{i,\tau 1,\tau 2,t}$ is actual net return to storage using RHS strategy from time $\tau 1$ to time $\tau 2$ of crop year t for region i of the state of Illinois. In equations (4) and (6), futures trade brokerage fees and liquidity costs are not included in the cost of unhedged storage.

To provide a sensitivity test of the performance of the basis strategy, we investigate two different scenarios for timing the selling of the stored crop. In the first scenario, the Illinois farmer sells the entire stored crop on the first Thursday in July. Thus, per bushel actual annual net return using this one-time-sale scenario for each crop and each strategy is:

$$(7) \qquad \mathrm{AR}^{\text{one-time}}_{i,\tau 1,\tau 2,t} = [b_i(\tau 2,t) - b_i(\tau 1,t)] - [\mathrm{P}(\tau 1,\tau 2,t) + \mathrm{I}_i(c_i,\tau 1,\tau 2,t) + \mathrm{BF}(t) + \mathrm{L}(t)]$$

where $\tau 1$ = one of the five storage initialization dates, and $\tau 2$ = the first week of July.

In the second scenario, the Illinois farmer sells an equal share[7] of the stored crop each Thursday beginning the week after storage is initiated and ending with the first Thursday in July. Actual net return using this multiple-sale scenario is calculated by averaging the net returns for all storage periods during the year as follows for each crop and each strategy:

$$(8) \qquad \mathrm{AR}^{\text{multiple}}_{i,\tau 1,\tau 2,t} = \frac{1}{N_t^*}\sum_{n=1}^{N_t^*} \mathrm{AR}^{\text{one-time}}_{i,\tau 1,(\tau 1+n),t}$$

where N_t^* = the number of weeks from initial storage date ($\tau 1$) to the first Thursday of July ($\tau 2$) for a crop year t. In this equation, N_t^* varies by crops and initial storage date but not by strategy.

Return and Risk Performance: t-test and F-test

We basically compare the means and standard deviations of the actual annual net storage returns for each situation indexed by s. Note that there are 80 situations, because the mean and standard deviation varies by sales scenario, crop, storage strategies, and initial storage date. In equation (9), the actual annual net storage returns ($\mathrm{AR}^s_{i,\tau 1,\tau 2,t}$) are first averaged across crop years for each situation and region to get $\overline{\mathrm{M}}^s_i$, and then we average $\overline{\mathrm{M}}^s_i$ across the seven Illinois regions to obtain a global mean of $\overline{\mathrm{M}}^s$ for each situation.

$$(9) \qquad \overline{\mathrm{M}}^s = \frac{1}{7}\sum_{i=1}^{7}(\mathrm{M}^s_i) = \frac{1}{7}\sum_{i=1}^{7}\left(\frac{1}{35}\sum_{t=1}^{35}\mathrm{AR}^s_{i,\tau 1,\tau 2,t}\right)$$

where $s = 1, 2, \cdots, 80$ = situation index[8].

[7] The share varies from 2.5 to 7.5 percent, depending on the initial storage date.

[8] We have 80 sets of ($\overline{\mathrm{M}}^s$, $\overline{\mathrm{SD}}^s$) because ($\overline{\mathrm{M}}^s$, $\overline{\mathrm{SD}}^s$) varies by sales scenarios, crops, storage strategies, and initial storage dates (2 sales scenarios × 2 crops × 4 strategies × 5 initial storage dates= 80). On the other hand, we have 560 sets of ($\overline{\mathrm{M}}^s_i$, $\overline{\mathrm{SD}}^s_i$) because ($\overline{\mathrm{M}}^s_i$, $\overline{\mathrm{SD}}^s_i$) varies by sales scenarios, crops, storage strategies, initial storage dates, and regions in Illinois (2 sales scenarios × 2 crops × 4 strategies × 5 initial storage dates × 7 Illinois regions = 560).

Similarly in equation (10), the standard deviation ($\overline{\text{SD}}_i^s$) of actual annual net storage returns ($\text{AR}_{i,\tau 1,\tau 2,t}^s$) is calculated for each Illinois region and each situation, and then the standard deviations ($\overline{\text{SD}}_i^s$) are averaged across the regions in Illinois to obtain an average standard deviation ($\overline{\text{SD}}^s$) for each situation s.

$$\overline{\text{SD}}^s = \frac{1}{7}\sum_{i=1}^{7}(\text{SD}_i^s) = \frac{1}{7}\sum_{i=1}^{7}\left(\frac{1}{35-1}\sum_{t=1}^{35}\left(\text{AR}_{i,\tau 1,\tau 2,t}^s - \text{M}_i^s\right)\right) \tag{10}$$

To illustrate the procedure to compare the means and standard deviations, assume that the return (risk) performance of the basis strategy is being examined for one-time-sale scenario, corn, and for hedged storage initiated at 50% harvest progress date. Then, we compare $\overline{\text{M}}^{s1}$ ($\overline{\text{SD}}^{s1}$) with $\overline{\text{M}}^{s2}$ (with $\overline{\text{SD}}^{s2}$), where $s1 =$ (one-time-sale scenario, corn, hedged, at 50% harvest, *routine strategy*), and $s2 =$ (one-time-sale scenario, corn, hedged, 50% harvest, *basis strategy*). To statistically analyze the return performance of the basis strategy, two-sample two-tailed paired t-tests are implemented for each situation. The null hypothesis of the t-tests is the equality of the actual annual net storage returns of routine strategy with those using the basis strategy. To examine the risk performance of the basis strategy, a similar statistical analysis is conducted using a two-tailed F-test with the null hypothesis that the variance of actual annual net storage returns of routine strategy equals the variance of returns from using the basis strategy for each equation. The two series of variables that are used for the paired t- and F-tests are $[\text{AR}_{i,\tau 1,\tau 2,t}^{s1}, \text{AR}_{i,\tau 1,\tau 2,t}^{s2}]_{t=1978}^{2005}$ for the pre-2006 period, and $[\text{AR}_{i,\tau 1,\tau 2,t}^{s1}, \text{AR}_{i,\tau 1,\tau 2,t}^{s2}]_{t=2006}^{2012}$ for the post-2005 period, for the same $s1$ and $s2$ as defined above and for each region. Given that the test results do not significantly vary across the regions in Illinois, we conduct and report the t- and F-tests using the aggregate data across the regions to conserve space.

Regression Analysis of Forecast Performance of Expected Returns to Storage (FE-PSUR)

The return-risk performance of the basis strategy depends on the performance of the expected net storage return to forecast[9] the observed net returns to storage. Thus, we examine the performance of this forecast for the pre-2006 period and the post-2005 period.

[9]While not directly related to forecast performance of the expected returns to storage by the change in the basis, the following observation does put this forecast performance in perspective. From a basic statistics formula, the variance of the cash-futures basis depends on variance of cash prices, variance of futures prices, and covariance between the two prices:

$$V(b) = V(c-f) = V(c) + V(f) - 2 * Cov(c,f) \tag{11}$$

where b, c, and f, are cash-futures basis, cash prices, and futures prices, respectively, and $V(\cdot)$ and $Cov(\cdot,\cdot)$ represent the variance of a single price and covariance of the two prices, respectively. Thus, the variance of the cash-futures basis will be smaller than the variance of the cash or futures price, if the following condition is satisfied:

$$Cov(c,f) \geq V(f)/2 \qquad (\text{or} \quad Cov(c,f) \geq V(c)/2) \tag{12}$$

It is possible to check if this relationship holds for this study. For the pre-2006 period, $V(c) = 0.29$, $V(f) = 0.25$, and $Cov(c,f) = 0.25$ for Illinois corn, thus the condition above is satisfied. Similarly, the condition has been satisfied for the post-2005 period with $V(c) = 2.39$, $V(f) = 1.92$, and $Cov(c,f) = 2.10$. When examining the relationship both for Illinois soybeans and for every seven-year intervals of the pre-2006 period for the sake of consistent comparison with the seven-year-long post-2005 period, this condition continues to hold in most cases. Thus, in general for this data set, the cash-futures basis is less variable than the cash and futures prices.

Our data set has a panel structure for each storage period and crop with two main variables, expected net return (ER) and actual net return (AR) as follows:

$$\text{(13)} \quad \text{ER}_{i,\tau 1,\tau 2,t} \text{ and } \text{AR}_{i,\tau 1,\tau 2,t} \quad (\text{for } i = 1, 2, \cdots, 7, \text{ and } t = 1978, 1979, \cdots, 2012)$$

Given the times series nature of the data, it is essential to check whether the individual time series variable is stationary before a regression analysis is launched. There are two time series variables, $\text{ER}_{i,\tau 1,\tau 2,t}$ and $\text{AR}_{i,\tau 1,\tau 2,t}$, for each Illinois region, crop, and storage period, totalling 140 time series variables. The Augmented Dickey-Fuller (ADF)[10] test rejects the null hypothesis of non-stationarity (i.e. unit root) for all the individual variables at least at the five percent significance level with the highest p-value of 0.041. Various panel-data unit-root tests including the Levin-Lin-Chu test and Im-Pesaran-Shin test are also implemented as a sensitivity check. The results from those tests consistently indicated that the time series variables are stationary with the highest p-value less than 0.001, implying the concern about potential spurious regressions is not necessary.

Given two crops grown in the same area and five different storage periods for each,[11] it is reasonable to expect that the unobserved heterogeneity which determines the level of actual storage return is correlated across the equations. Thus, a potential estimation issue is cross-equation correlations in disturbances. These correlations[12] across the individual equations are reported in Table 1. They range from +0.16 to +0.98 with an average correlation of +0.59. The average cross-equation correlation in disturbances between two equations for corn is +0.85, and +0.80 for soybeans equations. The correlation between one equation for corn and another equation for soybeans is +0.40 on average. The Breusch-Pagan test for no contemporaneous cross-equation correlations in disturbances rejects the null hypothesis at the one percent significance level.

Given the significant cross-equation correlations in disturbances, Seemingly Unrelated Regressions (SUR; Zellner, 1962) is chosen since SUR estimation provides more efficient estimates by capturing the cross-equation correlations and allows various tests for cross-equation restrictions. The superiority of SUR over pooled or equation-by-equation OLS for this particular type of analysis was suggested by Kahl and Tomek (1986). In their study on forward-pricing models for futures markets utilizing futures price[13] for different delivery months, they argue, "... if a small sample size is merely being duplicated, then this "pooling" is increasing our confidence in the wrong answer." They also contended that equation-by-equation OLS is inappropriate because it usually has a low degree of freedom, and because it may ignore additional information that is relevant and available.

Because this study is also interested in examining if there is any difference in the performance of the basis strategy among regions and during different time period and given the panel structure

[10]Regardless of whether trend and/or drift terms are considered, the ADF test results consistently indicated that each individual time series variable is stationary.

[11]We have 10 equations to estimate: corn and soybeans each has five equations, one for each storage period.

[12]These cross-equation correlations in disturbances are calculated using the residuals of equation-by-equation ordinary least squares estimations.

[13]The type of data used by Kahl and Tomek (1986) in their study is similar to the type of data used in this study. They used futures prices for different maturity months while this study uses data for different storage periods. For both data sets, residuals from equation-by-equation OLS are expected to be correlated as a result of unobserved heterogeneity held in common.

of the data, a Fixed Effects (FE) PSUR model (FE-PSUR)[14] is estimated:

$$
\begin{aligned}
\text{(14)} \qquad \mathrm{AR}^q_{i,t} &= \alpha^q_0 + \alpha^q_1 * \mathrm{ER}^q_{i,t} + \sum_{i=1}^{6} \alpha^q_{2,i} * \mathrm{R}_i + \sum_{i=1}^{6} \alpha^q_{3,i} * \mathrm{R}_i * \mathrm{ER}^q_{i,t} \\
&\quad + \alpha^q_4 * \mathrm{TD}_t + \alpha^q_5 * \mathrm{TD}_t * \mathrm{ER}^q_{i,t} + \mu^q_{i,t}
\end{aligned}
$$

where $q = 1,\ 2,\ \cdots,\ 10$ = equation index[15] the variables are for routine hedged storage and for one-time-sale scenario, $i = 1, 2, \cdots, 7$, $t = 1978, 1979, \cdots, 2012$, R_i = dummy variable for ith region of Illinois, $\mathrm{TD}_t = 1$ if t is in the post-2005 period, $\mu^{q1}_{i,t} \sim (0, \sigma^2_{q1})$, and $cov(\mu^{q1}_{i,t}, \mu^{q2}_{i,t}) \neq 0$ for any $q1 \neq q2$.

Also of interest is whether a one cent increase in ER forecasts a one cent increase in AR. This relationship implies a joint hypothesis that the intercept term equals zero while the slope coefficient equals one. In equation (14), α^q_0 and α^q_1 measure this forecast performance of the expected net returns to hedged storage for the pre-2006 period for each equation q.

We also are interested in whether the forecast performance varies for the post-2005 period relative to the pre-2006 period. The coefficients of TD (α^q_4) and the interaction term (α^q_5) between TD and ER capture the difference in forecast ability of AR by ER between the two sub-periods for each equation q.

Borrowing the standard forecast performance regression from Mincer and Zarnowitz (1969), joint hypothesis tests with the null hypothesis of $\alpha^q_0 = 0$ and $\alpha^q_1 = 1$ are implemented to measure the forecast performance[16] for the pre-2006 period for each equation q. Similar joint hypothesis with the null hypothesis of $\alpha^q_4 = 0$ and $\alpha^q_5 = 0$ are tested to check any difference in forecast behavior between the two sub-periods for each equation q. To illustrate these joint hypothesis tests, assume that $\mathrm{R}_1 = \mathrm{R}_2 = \cdots = \mathrm{R}_6 = 0$, in other words, assume without loss of generality that 7th Illinois region ($i = 7$) is being investigated. Then, the estimated forecast regression line from the second specification of FE-PSUR in equation (14) can be written as follows:

$$
\text{(15)} \qquad \widehat{\mathrm{AR}}^q_{i,t} = \hat{\alpha}^q_0 + \hat{\alpha}^q_1 * \mathrm{ER}^q_{i,t} \qquad \big(\text{for the pre-2006 period or } \mathrm{TD}_t = 0\big)
$$

$$
\text{(16)} \qquad \widehat{\mathrm{AR}}^q_{i,t} = (\hat{\alpha}^q_0 + \hat{\alpha}^q_4) + (\hat{\alpha}^q_1 + \hat{\alpha}^q_5) * \mathrm{ER}^q_{i,t} \qquad \big(\text{for the post-2005 period or } \mathrm{TD}_t = 1\big)
$$

In equation (15), we test for $H_0 : \alpha^q_0 = 0$ and $\alpha^q_1 = 1$ for each equation q. The null hypothesis is an unbiased forecast of AR by ER for the pre-2006 period. On the other hand, in equation (16) $H_0 : \alpha^q_4 = 0$ and $\alpha^q_5 = 0$ is tested for each equation q. The null hypothesis is no change in the forecast behavior by ER since the 2006 price run-up.

In similar, the coefficients, $\alpha^q_{2,i}$ and $\alpha^q_{3,i}$, measure the difference in the forecast ability among Illinois regions for each equation q and region i. Joint hypothesis tests with the null hypothesis of $\alpha^q_{2,i} = 0$ and $\alpha^q_{3,i} = 0$ are also implemented for each i to check the regional heterogeneity.

[14]The estimation is for the average value for Illinois. Results for the different regions are quite similar. Thus, to reduce the amount of space used to present results, the regression equation was estimated using the average value for Illinois.

[15]This index is slightly different from the situation index introduced in equations (9) and (10). The regression analysis only uses net storage returns for routine hedged storage strategy and one-time-sale scenario.

[16]Numerous empirical studies have applied this joint null hypothesis test in order to measure forecast performance. See Chernenko et al. (2004), Chinn et al. (2005), Reeve and Vigfusson (2011), and Krol (2014).

RESULTS

The basis strategy provides a signal for storage decisions. The share of the years in which the basis signal was to store were higher for corn than soybeans with range from 3% to 49% for corn and from 3% to 23% for soybeans. On average, the basis signal was to store in 20% of the observed crop years for corn, but only 9% for soybeans. Therefore, in most years the basis signal was not to store for Illinois corn and soybeans. As shown in Table 2, the existence of the heterogeneity both across seven Illinois regions and five storage periods in the share of the years in which the basis signal was to store is inconclusive.

The mean and standard deviation of annual net return to the routine and basis storage strategies are presented in Tables 3 and 4 for Illinois corn and soybeans. The means and standard deviations are the average across the seven regions for Illinois. We used the average to conserve space because the difference among regions is not large. The standard deviation of net storage return is consistently higher for the one-time sale scenario than for the multiple-sale scenario. This finding was expected because returns for the multiple-sale scenario are not dependent on the price of a single day. Because farmers and other storage agents usually make multiple sales of a stored crop, we focus our discussion on the results for the multiple-sale scenario.

Excluding only the storage of corn initiated on April 1 during the post-2005 period, the basis strategy improves the mean net storage return to hedge storage for both crops and all initial storage periods during both periods (left panel of Table 3). For corn, the improvement ranges from 4¢/bushel/year to 8¢/bushel/year during the pre-2006 period and from 2¢/bushel/year to 9¢/bushel/year during the post-2005 period. For soybeans, the improvement ranges from 6¢/bushel/year to 15¢/bushel/year for the pre-2006 period and by 2¢/bushel/year to 26¢/bushel/year for the post-2005 period. Excluding corn storage initiated at the 50% harvest date, two-sample paired t-tests for the pre-2006 period find that the higher returns resulting from using the basis strategy are statistically significant at the five percent significance test level. We did not conduct a statistical test for the post-2005 period due to the small number of observations (seven). Nevertheless, the finding that the basis strategy improved net return to hedged storage in 19 of the 20 scenarios examined is not inconsistent with the finding for the pre-2006 period that the basis strategy improves mean return for hedged storage.

For unhedged storage (right half of Table 3), the basis strategy improved the mean net return in the pre-2006 period except for soybeans at an initial storage date of 90 percent of harvest for the multiple-sale scenario. However, none of the improvements were statistically significant even at the ten percent test level. Moreover, for the post-2005 period, the basis strategy reduced mean storage return to unhedge storage except for corn with an initial storage date of April 1 in both the multiple-sale and one-time sale scenarios. These findings suggest that the basis strategy provides a profitable signal for storage decisions only when combined with a futures hedge. This finding is consistent with Heifner (1966) and Zulauf et al. (1998).

In contrast to the finding on mean annual net storage return, the basis strategy reduced the standard deviation of the annual net return for both hedged storage and unhedged storage for both Illinois corn and soybeans and for both the multiple-sale and one-time sale scenarios (Table 4). All of the F-tests are statistically significant at the one percent test level for the pre-2006 period. And, the standard deviation is smaller for all storage scenarios in the post-2006 period. The magnitude of reduction exceeded 50 percent for each storage scenario in the pre-2006 period and a majority of times exceeded 75 percent. The reduction was larger for unhedged storage than for hedged storage. The decline in standard deviation continued to be consistently large for hedged storage in the post-2005 period, but the magnitude of the decline in standard deviation of the return to unhedged storage was more variable in the post-2005 period, especially for storage initiated on April 1. To the authors' knowledge, no study has examined risk reduction of the basis strategy for unhedged storage.

The basis strategy is derived from the observation that expected net return to hedged storage calculated using the expected change in the basis (ER) provides an accurate prediction of actual net return to hedged storage (AR) (Working, 1953; and Heifner, 1966). Thus, to provide additional insight into the performance of the basis strategy, the forecasting relationship of AR by ER is examined.

The regression analysis of the forecasting relationship with two specifications is presented in Table 5. The first is the relationship between AR and ER plus an intercept term. The second adds dummy variables for the seven Illinois regions (R's), a time dummy variable (TD) that divides the observation period into the pre-2006 and post-2005 subperiods, an interaction term between ER and TD, and interaction terms between ER and R's.

No statistically significant difference was found by region in the forecast behavior of AR by ER. The coefficients of the regional dummy variables and the interaction terms between R's and ER were small in magnitude and consistently insignificant. These results are not presented in Table 5 in order to conserve space. The results can be obtained from the authors.

In Table 5, the coefficient of ER is positive and significantly different from zero for each equation in the 10-equation system, as expected. Thus, a strong positive association exists between AR and ER. The average estimated coefficient of ER across the equations with five different storage periods is +0.97 and +0.96 for corn and soybeans, respectively, implying that the slope coefficients are quite close to one. The intercepts are small, ranging from -0.03 to +0.01. The first panel in Table 6 reports the results from the joint hypothesis tests for a zero intercept and unit slope of the forecast equation for the pre-2006 period. The joint null hypothesis is not rejected for both corn and soybeans for any of the five storage periods. This finding is consistent with the finding that the basis storage strategy improved the returns to hedged storage.

Table 5 presents that the estimated coefficient of the interaction term between ER and TD is negative for all equations, and in seven equations they are statistically significant at the five percent significance level. The coefficient of TD is positive in nine equations, but only two of them are statistically significant at the five percent significance level. The second panel in Table 6 reports the joint hypothesis test of no change in forecast behavior by ER. Except for corn storage at 50 percent of harvest progress, we reject the null hypothesis at least at the five percent significance level. This finding implies that the forecast performance of ER has changed between the pre-2006 and post-2005 periods. To illustrate this change in the forecast performance of ER, equations (15) and (16)[17] can be rewritten using the estimated coefficients in Table 5 for, for example, the regression equation for corn storage initiated from 10% harvest progress[18] as follows:

$$(17)\quad \widehat{\mathrm{AR}}_{i,t}^{q} = \hat{\alpha}_0^q + \hat{\alpha}_1^q * \mathrm{ER}_{i,t}^q = 0.01 + 0.98 * \mathrm{ER}_{i,t}^q \quad \text{(for the pre-2006 period)}$$

$$(18)\quad \widehat{\mathrm{AR}}_{i,t}^{q} = (\hat{\alpha}_0^q + \hat{\alpha}_4^q) + (\hat{\alpha}_1^q + \hat{\alpha}_5^q) * \mathrm{ER}_{i,t}^q = 0.04 + 0.84 * \mathrm{ER}_{i,t}^q \quad \text{(for the post-2005 period)}$$

[17] As noted previously, equations (15) and (16) are expressed based on the assumption that 7th region in Illinois is being investigated. That is, $\mathrm{R}_i = 0$ for $i = 1, 2, \cdots, 6$ in equation (14).

[18] That is, q in equations (17) and (18) indicates the regression equation for the corn storage from 10% harvest progress date.

Equivalent equations for soybeans storage initiated from 10% harvest progress[19] is obtained as follows:

$$\widehat{\text{AR}}_{i,t}^{q} = \hat{\alpha}_0^q + \hat{\alpha}_1^q * \text{ER}_{i,t}^q = -0.00 + 1.00 * \text{ER}_{i,t}^q \quad \text{(for the pre-2006 period)} \tag{19}$$

$$\widehat{\text{AR}}_{i,t}^{q} = (\hat{\alpha}_0^q + \hat{\alpha}_4^q) + (\hat{\alpha}_1^q + \hat{\alpha}_5^q) * \text{ER}_{i,t}^q = 0.03 + 0.89 * \text{ER}_{i,t}^q \quad \text{(for the post-2005 period)} \tag{20}$$

As shown in equations (17)-(20), for this specific situation where the storage is initiated at 10% harvest completion date for each crop, the forecast performance appears to be unbiased during the pre-2006 period for both crops, but has been slightly deteriorated in the post-2005 period. The decline in forecast performance is consistent with the lack of convergence that has been noted in the soybean and especially corn futures markets during some of the years since 2006. However, given that the interpretation from a small sample size of the post-2005 period can be misleading, that the magnitude of deterioration is inconsistent across the storage periods for each crop, and that the direction of change in the forecast performance is not clear, the result has a limitation, and thus may not be conclusive.

R^2 is not reported for the FE-PSUR models in Table 5 because R^2 in SUR models may take negative values and may exceed one. Furthermore, R^2 generated by the Generalized Least Square, that is used in our SUR estimation, is not a properly-defined statistics, and thus can misinform.

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

Given the mixed results for the performance of the basis strategy in the previous literature and a rising concern about potential difficulty of accurate forecast of actual return to storage by expected return to storage due to the volatile basis levels since the 2006 price run-up, the study investigates the return and risk performance of the basis storage strategy over the 1975-2012 crop years for Illinois corn and soybeans. Also examined is the risk performance of the basis strategy for unhedged storage and cross-equation correlation in disturbances, topics not previously discussed in the literature.

To compare the means and standard deviations of actual annual net returns obtained from routine strategy and the basis strategy, t-tests and F-tests are implemented separately for two marketing scenarios, five different storage periods, two grains, and seven regions in Illinois. Since significant cross-equation correlations in disturbances are detected, a panel seemingly unrelated regression (PSUR) is estimated to measure the forecast ability of actual net return to storage by the expected net storage return. Given a panel structure of data for each equation and the interest on the regional heterogeneity in forecast behavior, a Fixed Effects (FE) model has been analyzed. Joint hypothesis tests using the results from FE-PSUR estimation are also implemented to examine if the forecast was unbiased for the pre-2006 period and if the forecast behavior has differed since the 2006 price run-up. Since location-level price data for seven production regions in Illinois has been used, the regional heterogeneity in return and risk performance as well as in the forecast behavior is also examined.

The analysis finds that the basis strategy improves net storage returns for hedged storage, but not for unhedged storage. This finding is consistent with previous studies. On the other hand, the basis strategy reduces the variance of net return to storage for both hedged and unhedged storage.

[19] That is, q in equations (19) and (20) indicates the regression equation for the soybeans storage from 10% harvest progress date.

A remarkable finding is that a considerable cross-equation correlation existed. The average cross-equation correlation in disturbances between two equations for corn is +0.85, and +0.80 for soybeans. More interestingly, the average correlation between one equation for corn and another equation for soybeans is +0.40 with a range from +0.16 to +0.61. This finding guided to more efficient estimation by providing the rationale for adopting a SUR model.

As shown in the joint hypothesis tests, the forecast of actual net return to storage by the expected net return to storage was unbiased in the pre-2005 period. However, the forecast performance changed in the post-2005 period, although whether the forecast overestimates or underestimates actual net return to storage is not clear and depends on the specific situation.

Future research may develop this analysis by using joint harvest progress of corn and soybeans to explore a potential source of cross crop correlation in storage returns. Given that little difference in the return and risk performance as well as in the forecast ability among seven Illinois regions existed, the Random Effects model (not the Fixed Effects model) may be considered in the future research. Finally, consideration of the role of physical storage capacity in impacting returns to storage and forecasting performance may provide interesting insights into the effectiveness of the basis strategy.

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Table 1. Cross-Equation Correlations in Disturbances in 10-Equation System[a], Illinois Corn and Soybeans, 1978-2012 Crop Years

	Corn					Soybeans				
Initial Time of Storage by Crop	10% Harvest	50% Harvest	90% Harvest	January 1	April 1	10% Harvest	50% Harvest	90% Harvest	January 1	April 1
Corn										
10% Harvest	1.00									
50% Harvest	0.95	1.00								
90% Harvest	0.93	0.98	1.00							
January 1	0.87	0.94	0.95	1.00						
April 1	0.72	0.73	0.73	0.72	1.00					
Soybeans										
10% Harvest	0.61	0.58	0.59	0.52	0.27	1.00				
50% Harvest	0.59	0.53	0.53	0.46	0.30	0.97	1.00			
90% Harvest	0.54	0.53	0.55	0.50	0.20	0.96	0.93	1.00		
January 1	0.34	0.36	0.34	0.31	0.28	0.76	0.79	0.76	1.00	
April 1	0.17	0.21	0.22	0.19	0.16	0.65	0.64	0.72	0.80	1.00
Breusch-Pagan[b] χ^2	4212.81									
p-value	< 0.000									

Note: (a) The model specification from which the cross-equation correlations are obtained contains intercept term, expected net return to hedged storage (ER), time dummy variable (TD) that divides entire period by the price run-up since 2006, an interaction term between TD and ER, regional dummy variables (R's), and interaction terms between R's and ER. This model is estimated by a 10-equation fixed effects panel seemingly unrelated regression. (b) Breusch-Pagan tests the assumption that the disturbances across the equations in the system are contemporaneously correlated. The null hypothesis for Breusch-Pagan is $\mathbf{H_0}$: "no contemporaneous cross-equation correlations in disturbances."

Data Source: Original calculations using data from U.S. Department Agriculture (USDA), Illinois Department of Agriculture, Chicago Mercantile Exchange, Weekly Weather and Crop Bulletin of USDA National Agricultural Statistics Service, and Federal Reserve Economic Data.

Table 2. Descriptive Statistics - Share[a] of Years the Basis Signaled to Store, Illinois Corn and Soybeans, 1978-2012 Crop Years

	Regions in Illinois							
Initial Time of Storage by Crop	Northern	Western	North Central	South Central	Wabash	West S.Western	Little Egypt	Mean[b]
Corn								
10% Harvest	11%	17%	14%	17%	29%	29%	34%	22%
50% Harvest	26%	31%	29%	20%	46%	40%	49%	34%
90% Harvest	23%	14%	9%	9%	29%	26%	29%	20%
January 1	6%	3%	3%	6%	9%	3%	11%	6%
April 1	17%	14%	11%	20%	26%	20%	26%	19%
Mean[c]	17%	16%	13%	14%	28%	24%	30%	20%[d]
Soybeans								
10% Harvest	6%	6%	3%	3%	6%	9%	14%	7%
50% Harvest	6%	6%	3%	3%	14%	9%	17%	8%
90% Harvest	11%	9%	9%	6%	20%	17%	23%	14%
January 1	6%	3%	3%	3%	3%	3%	6%	4%
April 1	11%	11%	14%	17%	14%	20%	17%	15%
Mean[c]	8%	7%	6%	6%	11%	12%	15%	9%[d]

Note: (a) The share is based on the 35 crop years from 1978 through 2012. (b) The mean is across the Illinois regions for each given storage period. (c) The mean is across the storage periods for each given Illinois region. (d) The mean is the average of all the 35 shares (5 initial storage dates $\times$ seven regions) for each crop.

Data Source: Original calculations using data from U.S. Department Agriculture (USDA), Illinois Department of Agriculture, Chicago Mercantile Exchange, Weekly Weather and Crop Bulletin of USDA National Agricultural Statistics Service, and Federal Reserve Economic Data.

Table 3. Return Performance of Basis Strategy - t-test[a] Results for Multiple-Sale Scenario and One-Time-Sale Scenario, Illinois Corn and Soybeans, 1978-2012 Crop Years

Unit: $/Bushel	Mean of Annual Net Returns to Hedged Storage					Mean of Annual Net Return to Unhedged Storage				
	1978-2005 Crop Years			2006-2012 Crop Years[b]		1978-2005 Crop Years			2006-2012 Crop Years[b]	
Initial Time of Storage by Crop	Routine Strategy	Basis Strategy	t-stat[c]	Routine Strategy	Basis Strategy	Routine Strategy	Basis Strategy	t-stat[c]	Routine Strategy	Basis Strategy
Multiple-Sale Scenario[d]										
Corn										
10% Harvest	-0.03	0.02***	2.91	-0.07	0.02	0.00	0.01	0.09	0.21	0.10
50% Harvest	0.01	0.05*	2.04	-0.02	0.03	0.04	0.04	-0.03	0.24	0.04
90% Harvest	-0.05	0.01***	3.92	-0.03	0.02	-0.04	0.01	1.27	0.15	0.03
January 1	-0.08	0.00***	6.66	-0.01	0.01	-0.03	-0.01	0.61	0.14	-0.05
April 1	-0.04	0.00***	5.14	0.01	0.00	-0.04	-0.01	1.40	0.01	0.05
Soybeans										
10% Harvest	-0.10	0.01***	3.99	-0.19	0.07	-0.11	-0.01	0.77	0.79	0.06
50% Harvest	-0.06	0.01**	2.26	-0.11	0.03	0.02	0.02	0.05	1.13	0.20
90% Harvest	-0.05	0.03**	2.14	-0.15	0.04	0.00	-0.02	-0.21	0.64	0.07
January 1	-0.15	0.00***	8.46	-0.11	0.00	-0.08	-0.02	0.61	0.39	0.00
April 1	-0.06	0.00***	4.90	-0.01	0.01	-0.02	0.02	0.60	0.63	0.23
One-Time-Sale Scenario[e]										
Corn										
10% Harvest	-0.12	-0.01***	5.04	-0.05	-0.01	-0.08	-0.03	0.53	0.78	0.27
50% Harvest	-0.09	0.03***	3.86	-0.08	0.03	-0.05	0.04	0.93	0.62	0.08
90% Harvest	-0.15	-0.00***	5.11	-0.10	0.02	-0.12	0.02	1.55	0.50	0.08
January 1	-0.16	-0.00***	7.99	0.17	0.01	-0.11	-0.00	1.20	0.18	-0.05
April 1	-0.10	-0.01***	5.26	-0.15	-0.01	-0.11	-0.01	1.84	0.04	0.11
Soybeans										
10% Harvest	-0.28	0.00***	6.48	-0.24	0.03	-0.24	-0.02	0.95	2.60	0.51
50% Harvest	-0.24	0.00***	4.97	-0.18	0.01	-0.12	0.04	0.69	2.92	0.67
90% Harvest	-0.22	0.01***	4.14	-0.22	0.02	-0.12	-0.04	0.42	2.30	0.20
January 1	-0.29	-0.01***	9.82	-0.32	0.00	-0.19	-0.01	1.02	1.48	0.00
April 1	-0.15	-0.01***	6.67	-0.20	-0.02	-0.13	0.02	1.11	1.44	0.62
Number of Observations	28	28		7	7	28	28		7	7

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. (a) For two-tailed two-sample paired t-tests for the equality of means, the null hypothesis was $\mathbf{H_0} : \bar{M}_{RHS} = \bar{M}_{BSHS}$ for hedged storage for each grain and each initial storage date, and was $\mathbf{H_0} : \bar{M}_{RUS} = \bar{M}_{BSUS}$ for unhedged storage for each grain and each initial storage date. (b) For the sub-period of 2006-2012 crop years, t-tests statistics and its significance are not displayed in the table due to its questionable power given the small sample size of 7 observations. (c) Positive values of t-statistics imply an improvement in annual net storage returns by the basis strategy. (d) In multiple-sale scenario, an Illinois farmer sells an equal portion of the stored grain on each Thursday through the first Thursday of July beginning with the Thursday after the initial storage date. (e) In one-time-sale scenario, the Illinois farmer sells all of the crop on the first Thursday in July.

Data Source: Original calculations using data from U.S. Department Agriculture (USDA), Illinois Department of Agriculture, Chicago Mercantile Exchange, Weekly Weather and Crop Bulletin of USDA National Agricultural Statistics Service, and Federal Reserve Economic Data.

Table 4. Risk Performance of Basis Strategy - F-test[a] Results for Multiple-Sale Scenario and One-Time-Sale Scenario, Illinois Corn and Soybeans, 1978-2012 Crop Years

Unit: $/Bushel	Standard Deviations of Annual Net Returns to Hedged Storage					Standard Deviations of Annual Net Returns to Unhedged Storage				
	1978-2005 Crop Years			2006-2012 Crop Years[b]		1978-2005 Crop Years			2006-2012 Crop Years[b]	
Initial Time of Storage by Crop	Routine Strategy	Basis Strategy	F-stat	Routine Strategy	Basis Strategy	Routine Strategy	Basis Strategy	F-stat	Routine Strategy	Basis Strategy
Multiple-Sale Scenario[c]										
Corn										
10% Harvest	0.02	0.01***	6.90	0.08	0.02	0.05	0.01***	45.73	0.49	0.16
50% Harvest	0.03	0.01***	3.97	0.05	0.02	0.05	0.02***	11.13	0.31	0.07
90% Harvest	0.02	0.00***	23.96	0.05	0.02	0.04	0.01***	24.91	0.28	0.07
January 1	0.01	0.00***	204.05	0.05	0.01	0.04	0.01***	38.57	0.21	0.05
April 1	0.01	0.00***	8.69	0.03	0.02	0.03	0.01***	5.79	0.10	0.04
Soybeans										
10% Harvest	0.03	0.00***	44.22	0.17	0.05	0.13	0.01***	786.08	0.50	0.05
50% Harvest	0.03	0.01***	30.26	0.13	0.03	0.12	0.02***	67.50	0.52	0.18
90% Harvest	0.04	0.01***	14.01	0.13	0.04	0.10	0.02***	22.39	0.47	0.07
January 1	0.02	0.00***	602.78	0.05	0.00[e]	0.10	0.02***	24.84	0.28	0.00[e]
April 1	0.01	0.00***	18.36	0.03	0.02	0.07	0.01***	26.08	0.29	0.22
One-Time-Sale Scenario[d]										
Corn										
10% Harvest	0.03	0.01***	16.61	0.09	0.05	0.11	0.02***	24.90	0.82	0.44
50% Harvest	0.04	0.02***	6.25	0.10	0.03	0.11	0.04***	6.04	0.57	0.18
90% Harvest	0.03	0.00***	51.80	0.10	0.03	0.10	0.02***	19.98	0.56	0.17
January 1	0.02	0.00***	891.41	0.10	0.01	0.09	0.00***	585.44	0.41	0.05
April 1	0.02	0.01***	12.54	0.11	0.03	0.07	0.03***	4.74	0.30	0.19
Soybeans										
10% Harvest	0.04	0.00***	344.72	0.12	0.02	0.24	0.01***	668.45	0.84	0.32
50% Harvest	0.05	0.00***	> 999	0.08	0.01	0.23	0.03***	58.18	0.95	0.61
90% Harvest	0.06	0.00***	185.19	0.10	0.02	0.22	0.05***	22.05	0.91	0.21
January 1	0.03	0.01***	10.71	0.08	0.00[e]	0.18	0.01***	464.79	0.68	0.00[e]
April 1	0.02	0.01***	7.61	0.10	0.02	0.15	0.04***	19.59	0.54	0.54
Number of Observations	28	28		7	7	28	28		7	7

Note: *** $p < 0.01$. (a) For F-tests for the equality of variances, the null (alternative) hypothesis was $\mathbf{H_0}: \sigma^2_{\text{RHS}} = \sigma^2_{\text{BSHS}}$ ($\mathbf{H_1}: \sigma^2_{\text{RHS}} > \sigma^2_{\text{BSHS}}$) for hedged storage for each grain and each initial storage date, and was $\mathbf{H_0}: \sigma^2_{\text{RUS}} = \sigma^2_{\text{BSUS}}$ ($\mathbf{H_1}: \sigma^2_{\text{RUS}} > \sigma^2_{\text{BSUS}}$) for unhedged storage for each grain and each initial storage date. (b) For the sub-period of 2006-2012 crop years, F-tests statistics and its significance are not displayed in the table due to its questionable power given the small sample size of 7 observations. (c) In multiple-sale scenario, an Illinois farmer sells an equal portion of the stored grain on each Thursday through the first Thursday of July beginning with the Thursday after the initial storage date. (d) In one-time-sale scenario, the Illinois farmer sells all of the crop on the first Thursday in July. (e) For the soybeans storage initiated from January 1 for the latter sub-period of 2006-2012 crop years, there was no year in which the basis strategy was to store, thus the annual net returns for the 7 crop years of the sub-period were all zero. Hence, the standard deviation was zero.

Data Source: Original calculations using data from U.S. Department Agriculture (USDA), Illinois Department of Agriculture, Chicago Mercantile Exchange, Weekly Weather and Crop Bulletin of USDA National Agricultural Statistics Service, and Federal Reserve Economic Data.

Table 5. Forecast Performance of Actual Net Returns to Hedged Storage by Expected Net Returns to Hedged Storage: Estimation Result for 10-Equation Fixed Effect Panel Seemingly Unrelated Regressions (FE-PSUR), Illinois Corn and Soybeans, 1978-2012 Crop Years

	Corn: Actual Return ($/Bushel)		Soybeans: Actual Return ($/Bushel)	
	FE-PSUR Estimations		FE-PSUR Estimations	
	(1)[a]	(2)[a,b,c]	(1)[a]	(2)[a,b,c]
From 10% Harvest				
Expected Return	0.99***	0.98***	0.98***	1.00***
(= ER)	(0.01)	(0.03)	(0.01)	(0.03)
$TD_{t,2006}$		0.03		0.03
		(0.02)		(0.03)
$TD_{t,2006}$ * ER		-0.14***		-0.11***
		(0.04)		(0.03)
Intercept	0.02	0.01	0.00	-0.00
	(0.02)	(0.02)	(0.03)	(0.03)
From 50% Harvest				
Expected Return	0.99***	1.00***	0.99***	1.00***
(= ER)	(0.01)	(0.02)	(0.01)	(0.03)
$TD_{t,2006}$		0.04*		0.00
		(0.02)		(0.03)
$TD_{t,2006}$ * ER		-0.03		-0.21***
		(0.03)		(0.04)
Intercept	0.02	0.01	0.00	-0.00
	(0.02)	(0.02)	(0.03)	(0.03)
From 90% Harvest				
Expected Return	0.99***	0.99***	0.99***	1.00***
(= ER)	(0.01)	(0.03)	(0.01)	(0.02)
$TD_{t,2006}$		0.03*		0.04
		(0.02)		(0.03)
$TD_{t,2006}$ * ER		-0.08**		-0.08*
		(0.03)		(0.05)
Intercept	0.01	0.01	0.00	-0.00
	(0.02)	(0.02)	(0.03)	(0.03)
From January 1				
Expected Return	0.97***	0.95***	0.89***	0.94***
(= ER)	(0.01)	(0.06)	(0.02)	(0.06)
$TD_{t,2006}$		0.03		-0.08**
		(0.02)		(0.03)
$TD_{t,2006}$ * ER		-0.13*		-0.43***
		(0.07)		(0.07)
Intercept	0.01	0.00	-0.03	-0.02
	(0.02)	(0.02)	(0.03)	(0.03)
From April 1				
Expected Return	0.90***	0.90***	0.77***	0.84***
(= ER)	(0.02)	(0.06)	(0.03)	(0.08)
$TD_{t,2006}$		0.03**		0.04
		(0.02)		(0.02)
$TD_{t,2006}$ * ER		-0.35***		-0.15***
		(0.06)		(0.06)
Intercept	0.01	0.00	-0.03	-0.03
	(0.02)	(0.02)	(0.02)	(0.02)
Number of Observations[d]	230	230	230	230
R^2 [e]	-	-	-	-

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. (a) The specification contain region-specific fixed effects, but they are not included in this table to simplify the presentation of results. The region-specific fixed effects were tiny and consistently insignificant. (b) For the same reasons, results are not reported for the interaction terms between regional dummy variables (R's) and the expected net return to hedged storage (ER) that are included in the regression equations to examine if the forecast performance varies by regions in Illinois for each grain and each storage initialization point. (c) We also ran regression equations with time dummy variable that divides entire year by the 2006 price run-up and its interaction term with ER, but without the interaction terms between R's and ER. We found no consistent change in the magnitude and significance of any of the coefficients, thus the results are excluded in this table. (d) Number of observations is for each individual equation in the 10-equation system. (e) R^2 values for FE-PSUR estimations are not reported due to its inappropriateness that is explained in the body of the article, while those for equation-by-equation FE estimations are 0.62, 0.73, 0.63, 0.42, and 0.48 for the five equations of corn, and 0.62, 0.67, 0.72, 0.30, and 0.31 for the other five equations of soybeans.

Data Source: Original calculations using data from U.S. Department Agriculture (USDA), Illinois Department of Agriculture, Chicago Mercantile Exchange, Weekly Weather and Crop Bulletin of USDA National Agricultural Statistics Service, and Federal Reserve Economic Data.

Table 6. Joint Hypothesis Test of Forecast Performance of Actual Net Returns to Hedged Storage by Expected Net Returns to Hedged Storage, Illinois Corn and Soybeans, 1978-2012 Crop Years

	Corn Storage From					Soybeans Storage From				
Statistics	10% Harvest	50% Harvest	90% Harvest	January 1	April 1	10% Harvest	50% Harvest	90% Harvest	January 1	April 1
(A) Joint Hypothesis Tests for Perfect Forecast for Pre-2006 Period ($\mathbf{H_0}: \alpha_0 = 0$ and $\alpha_1 = 1$)										
χ^2	0.66	0.40	0.52	1.25	2.87	0.03	0.02	0.06	1.04	3.60
p-value	0.72	0.82	0.77	0.53	0.24	0.98	0.99	0.97	0.60	0.17
(B) Joint Hypothesis Tests for "No Change" in Forecast Behavior Since 2006 Price Run-Up ($\mathbf{H_0}: \alpha_4 = 0$ and $\alpha_5 = 0$)										
χ^2	15.29	4.86	9.95	8.57	40.60	22.89	39.85	7.85	43.30	13.98
p-value	0.00	0.09	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.01

Note: (a) All joint hypothesis tests are implemented using results from 10-equation fixed effects panel seemingly unrelated regression estimation that contains intercept term, expected net return to hedged storage (ER), time dummy variable (TD) that divides entire period by the price run-up since 2006, an interaction term between TD and ER, regional dummy variables (R's), and interaction terms between R's and ER as independent variables.

Data Source: Original calculations using data from U.S. Department Agriculture (USDA), Illinois Department of Agriculture, Chicago Mercantile Exchange, Weekly Weather and Crop Bulletin of USDA National Agricultural Statistics Service, and Federal Reserve Economic Data.