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Forecasting Returns to Storage: The Role of Factors other than the Basis Strategy

Sangyo Kim Carl Zulauf Matthew Roberts

Abstract

Given the interest in the ability to forecast returns to storage and the inconclusiveness of the performance of the basis strategy, especially for unhedged storage; this study examines whether other variables enhance the forecast of storage returns. Specifically, the rate of harvest progress and the ratio of a demand for storage space relative to the supply of storage space are examined. The later variable has not been investigated by previous studies of the basis strategy. Using data for Illinois corn and soybeans over the 1988 through 2012 crop years and a fixed effect seemingly unrelated regression estimation, both variables are found to be significant in explaining observed returns to unhedged storage but not to hedged storage. Given the regression results, storage strategies based on harvest progress and ratio of demand to supply for storage space are constructed. These strategies do not improve the basis strategy's return and risk for hedged storage. In contrast, these strategies improve the return and risk performance of unhedged storage relative to routine unhedged storage. Moreover, net return for the alternative strategies for unhedged storage is higher than net return for the basis strategy for hedged storage but the latter has a lower risk than the former. This finding is the classic return-risk tradeoff and provides an explanation for the common observation that storage is often unhedged, especially by farmers.

Key words: basis strategy, harvest progress, return to storage, return risk, selective storage, storage capacity
JEL codes: G14, G17, Q11, Q13

1 Introduction

Forecasting 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 expected change in the futures-cash basis exceeds the cost storage. Working argued the basis strategy could be profitable since changes in the cash-futures basis are more predictable than changes in cash or futures prices. Existing studies generally find support for the strategy, especially for storage that is hedged (Heifner, 1966, Zulauf and Irwin, 1998, and Siaplay et al., 2012), but Kastens and Dhuyvetter (1999) find inconsistent support.

All of these studies are univariate analyses that examine whether actual net returns to storage can be explained by the expected net returns predicted by the basis strategy. For univariate analyses, an omitted variable bias may exist if the basis strategy's measure of expected net return to storage does not fully capture other explanatory variables. Therefore, this study adds to the literature by examining whether other variables add to the basis strategy's explanation of observed returns to storage. It specifically focuses on two variables that have been mentioned in the literature: the rate of harvest progress (Zulauf et al., 1998-1999; Kim, Zulauf, and Roberts, 2014) and storage space (Working, 1953a; Brennan, 1958; Barry and Fraser, 1976; Beal, 1996; Saha and Stroud, 1994; Park, 2006).

Using data for Illinois corn and soybeans and a Fixed Effects Panel Seemingly Unrelated Regressions (FEP-SUR) estimation, both variables are found to significantly add explanatory power to the basis storage strategy, especially for unhedged storage. Given this finding, storage strategies based on harvest progress and the ratio of demand to supply for storage space are constructed. While these strategies do not improve upon the return or risk performance of the basis strategy for hedged storage; for unhedged storage they improve upon the return performance of the basis strategy and also upon both the return and risk performance of routine unhedged storage every year. This finding suggests that successful, simple storage strategies exist not just for hedged storage but unhedged storage. Moreover, both return and risk is higher for the alternative strategies using unhedged storage than for hedged storage using the basis strategy. This finding is the classic return-risk tradeoff and is consistent with the common observation that storage is often unhedged, especially by farmers (Brorsen, 1995; Collins, 1997; Carter, 1999; Peterson and Tomek, 2007; Pannell et al., 2008).

The rest of the article is organized as follows. Studies of the basis strategy are reviewed. Then the procedures and methods used in the empirical analysis are described, followed by a discussion of findings. The paper closes with conclusions and implications.

2 Literature Review

The Efficient Market Hypothesis, a key concept in the study of speculative prices, states an efficient market completely and accurately incorporates all available, publicly known information at the time price is determined (Fama, 1970). Because 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, models that predict future cash prices also are generally found to be unreliable indicators of the returns to storage (Working, 1953b; Tomek and Peterson, 2005; Reichsfeld and Roache, 2011). However, Working (1953a) argued the basis, or difference between cash and futures prices, can guide profitable inventory control. He presented empirical evidence of a significant relationship between the initial cash-futures basis and actual gross return to subsequent storage hedged until the delivery month for Kansas City wheat (Working, 1953b). His data spanned the 1922-1952 crop years . Based on his findings, Working proposed a strategy, subsequently called the basis strategy, of storing only when the expected change in the cash-futures basis exceeds the cost of storage.

Since Working's seminal article, several studies have investigated the basis strategy. Heifner (1966), using a linear regression for 1952-1965 Michigan corn prices, found the initial cash-futures basis explains, on average over the different storage intervals investigated, 74 percent of the variation in gross return to hedged storage but only six percent of the variation in gross return to storage that was not hedged, or unhedged storage. Based on these findings and Monte Carlo simulations of net storage returns at different hypothesized levels of storage costs, Heifner concluded the basis strategy generally improved net returns to hedged storage relative to routine hedged storage. Heifner also found that the basis strategy reduced the standard deviation of the net returns to hedged storage and that its usefulness varied by storage interval.

Distinctive from Heifner's Monte Carlo approach, Zulauf et al. (1998-1999; also reported in Zulauf and Irwin, 1998) forecast expected net return to storage by using a moving average of the previous 3 years' basis at the end of the storage period. Their examination of Ohio corn for 1964-1997 found the basis strategy increased net return to storage but only when combined with a futures hedge. In accordance with Heifner's suggestion to examine different storage periods, net storage return at the 50 percent harvest completion date was found to be significantly higher than at either the 10 percent or 90 percent harvest completion dates. Zulauf et al. also found the basis strategy reduced the standard deviation of net storage returns for hedged storage, but did not investigate its impact on risk for unhedged storage.

Using a methodology similar to Zulauf et al., Kastens and Dhuyvetter (1999), however, 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."

Siaplay et al. (2012) used regression analysis to examine if the expected change in the basis provides a profitable market signal for making storage decisions. They examined Oklahoma wheat prices from 1975 through 2005. Expected change in the basis was calculated using a moving average basis of the previous 5 years. This measure of the basis strategy signal was found to be a useful predictor of net returns for both hedged and unhedged storage, but its forecasting power was higher for hedged storage.

Kim, Zulauf, and Roberts (2014) found that, for Illinois corn and soybeans over the 1975-2005 crop years and relative to routinely storing each year, the basis strategy improved net return to hedged but not unhedged storage and reduced return risk for both types of storage. These findings also generally held for the post-2005 price increase period although no statistical test was conducted due to a small sample. The analysis included three harvest and two post-harvest dates. Measured in dollar per bushel, expected net return to storage was an unbiased estimate of observed net storage return in the pre-2006 period, but some forecasts were biased in the post-2005 period. Forecast performance was analyzed using Fixed Effects Panel Seemingly Unrelated Regressions because significant cross-equation correlations were found in the disturbances for the corn and soybean equations.

3 Predictive Performance of Basis Strategy

3.1 General Procedures

Beginning with Working's original analysis published in 1953, a standard performance test of the basis storage signal is to compare actual return to storage with the basis strategy's predicted return to storage (Heifner, 1966; Siaplay et al., 2012; Kim, Zulauf, and Roberts, 2014). Actual return can be calculated for unhedged and hedged storage. Unhedged storage return depends on changes in cash market prices once storage begins. Hedged storage return depends on the relative change in cash and futures prices, or the change in the basis, since hedged storage involves taking a short futures position while storing the crop. The short futures hedge is closed out by buying back the futures contract when the cash commodity is sold.

Per bushel net return to unhedged storage (AR^{US}) and hedged storage (AR^{HS}) expressed as a percent of the cash price at harvest (*i.e.*, percent net return to storage over the interval from $\tau 1$ to $\tau 2$ of crop year t) is calculated:

$$
\begin{aligned}
AR^{US}_{\tau 1,\tau 2,t} &= \frac{\left[c\left(\tau 2,t\right)-c\left(\tau 1,t\right)\right]-\left[P\left(\tau 1,\tau 2,t\right)+I\left(\tau 1,\tau 2,t\right)\right]}{c\left(\tau 1,t\right)} \\
AR^{HS}_{\tau 1,\tau 2,t} &= \frac{\left[b\left(\tau 2,t\right)-b\left(\tau 1,t\right)\right]-\left[P\left(\tau 1,\tau 2,t\right)+I\left(\tau 1,\tau 2,t\right)+BF\left(t\right)+L\left(t\right)\right]}{c\left(\tau 1,t\right)}
\end{aligned} \tag{1}
$$

where $c\left(\tau,t\right)$ = cash price at time $\tau 1$ of crop year t, $b\left(\tau,t\right)=c\left(\tau,t\right)-f\left(\tau,t\right)$ = cash−futures basis, $f\left(\tau,t\right)$ = futures price, P = per bushel physical storage cost to keep a commodity in useable condition, I = per bushel interest opportunity cost[2] that varies with the cash price and interest rate at the initial storage date as well as the length of the storage interval, BF = per bushel brokerage fee of futures trade, and L = per bushel liquidity cost of futures trade.

Predicted percent net return to hedged storage, designated ER, over the storage interval equals:

$$
ER_{\tau 1,\tau 2,t} = \frac{\left[\widehat{b_{\tau 1}}\left(\tau 2,t\right)-b\left(\tau 1,t\right)\right]-\left[P\left(\tau 1,\tau 2,t\right)+I\left(\tau 1,\tau 2,t\right)+BF\left(t\right)+L\left(t\right)\right]}{c\left(\tau 1,t\right)} \tag{2}
$$

where $\widehat{b_{\tau 1}}\left(\tau 2,t\right)$ = basis expected at $\tau 2$ as of $\tau 1$ of crop year $t = \left[\frac{1}{3}\sum_{k=1}^{3} b\left(\tau 2,t-k\right)\right]$. Various techniques exist for forecasting basis; 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. Jiang and Hayenga (1998) found a three-year moving average was a reasonably accurate basis forecast for U.S. corn and soybeans. Zulauf et al. (1998) and Kim, Zulauf, and Roberts (2014) used a three-year moving average for Ohio corn and Illinois corn and soybeans, respectively. Taylor, Dhuyvetter and Kastens (2004) recommended a two-year average for Kansas corn and three-year average for Kansas soybeans. Hatchett, Brorsen, and Anderson (2010) found no statistical difference in forecast errors for moving averages of less than four years for Illinois corn and soybeans. Given this literature, we chose to use a three-year moving average.

Per bushel opportunity cost is calculated:

$$
I\left(\tau 1,\tau 2,t\right)=c\left(\tau 1,t\right)\times IR\left(\tau 1,t\right)\times\frac{\left[7\times\left(\tau 2-\tau 1\right)\right]}{365} \tag{3}
$$

where $IR\left(\tau 1,t\right)$ = interest rate at $\tau 1$ of crop year t, and $\left(\tau 2-\tau 1\right)$ = length of storage interval in weeks.

[2]A third storage cost is insurance purchased to cover the physical destruction of the stored commodity. Consistent with the previous studies discussed in the literature review, insurance cost is not included in the analysis because of its small size.

Prediction of actual net return to storage by a single variable, expected net return to storage, may suffer from an omitted variable bias if expected net return does not fully capture other potential explanatory variables. This study therefore adds to the literature by examining if variables other than expected net return explain observed net return to storage.

Previous studies found net return to storage varied by the time of harvest at which storage is initiated (Zulauf et al., 1998; Kim, Zulauf, and Roberts, 2014). Both studies find that net storage return is higher for storage that begins at the 50 percent harvest completion date than at either the 10 percent or 90 percent harvest completion date. This study furthers this line of investigation but uses a different approach. Specifically, harvest completion rate as of the initial storage date is added as an independent variable to the regression equation.

The second added independent variable is the ratio of demand for storage bin space relative to the supply of storage bin space. The greater the demand relative to supply of storage bin space, the higher the net return to storage is expected to be. Early mentions of storage space were by Working (1953a) and Brennan (1958), followed by a series of studies (Barry and Fraser, 1976; Beal, 1996; Saha and Stroud, 1994; Park, 2006).

Net return to storage is calculated assuming all of the stored crop is sold on the first Thursday in July, or at the end of the storage period. More complex storage strategies could be investigated as in Peterson and Tomek (2007) and Wisner, Blue, and Baldwin (1998), such as placing storage hedges in the March futures contract and then rolling the storage hedge to a later contract until corn or soybeans are sold in the cash market. This study opted for a simple storage strategy because our interest is the base level return to storage, not the potential to enhance return by adopting a more dynamic storage strategy.

3.2 Data, Variables, and Estimation Framework

Cash prices used in this analysis are average prices paid to Illinois farmers by country elevators on Thursdays during the 1988-2012 crop years[3]. They are available for seven Illinois regions[4] from the U.S. Department of Agriculture (USDA) and Illinois Department of Agriculture.

[3]The analysis is not able to use data for the 2013-2014 crop year because the shutdown of the federal government from October 1 through 16, 2013 resulted in no collection of cash prices.

[4]While not elevator specific data, as used by Kastens and Dhuyvetter (1999), regional data are less aggregated than state data used by Zulauf et al. (1998), Siaplay et al. (2012), and Kim, Zulauf, and Roberts (2014). The seven Illinois regions are designated Northern, Western, North Central, South Central, Wabash, West Southwestern, and Little Egypt.

The storage hedge is placed in the July futures contract traded in Chicago. The July contract 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 contract is used for soybeans. A September futures contract is traded for corn and soybeans, but it may trade as a new crop contract if corn and soybean harvest is expected to be early. The settlement price for the July futures contract is collected for the same date as the cash prices are available[5]. Source of the futures prices is Barchart.com.

Initial storage date is the second Thursday of October because this is the first date for which data are available for all years and both crops. Ending storage date is the first Thursday of July. Selection of this date avoids problems that can emerge later in the delivery month resulting from availability of deliverable supplies on the futures contract. Length of the storage period is thus 38 weeks.

The interest rate used to calculate storage opportunity cost is the annual bank prime loan rate as of the second Thursday of October. Source is the Federal Reserve Economic Data (FRED) maintained by the Federal Reserve Bank of St. Louis. Average annual prime loan rate is 6.6 percent with a range of 3.3 to 11.5 percent (see Table 1).

Physical storage cost is from USDA, Commodity Credit Corporation (CCC) through the 2008 crop year. CCC then changed the method used to report storage rates by commodity, resulting in substantially higher rates. Thus, for the more recent years, physical storage rates are from an Ohio country elevator, cross checked with another Ohio elevator. This rate is more consistent with CCC storage rates prior to 2009. Average per bushel storage rate is 39 cents per year with a range of 33 to 60 cents (see Table 1).

A brokerage fee of $50 is used for a round trip buying and selling of a futures contract. Liquidity cost of trading futures arises because trades cannot be executed instantly and futures price changes. Thus, the price at which a futures trade is executed likely differs from the price at which the trade is placed. Based on Brorsen (1989) and Thompson and Waller (1987), liquidity cost is calculated as $25 per futures trade made before February 1 and $12.50 thereafter. Liquidity cost declines because trading volume increases as contract maturity approaches, reducing the difference between execution and placed price. Per bushel brokerage and liquidity costs are calculated by dividing by 5,000 bushels, the size of corn and soybean futures contracts.

Harvest progress rates, designated HPR, are from the *Weekly Weather and Crop Bulletin* jointly published by USDA and the Department of Commerce. Progress rate is reported as of Sunday (USDA, National Agricultural Statistics Service (NASS))

[5] If Thursday was a holiday, the cash price was assumed to be for the preceding Wednesday. Most Thursday holidays were Thanksgiving.

using survey[6] data. Because Thursday prices are used in the analysis, the harvest progress rates for the Sunday preceding the given Thursday are used as this is the latest available report to the market. Harvest progress rates vary widely by crop year, ranging from 5 percent to 87 percent for corn and from 6 percent to 79 percent for soybeans (see Table 1). Both minimums occurred in the 2009-2010 crop year while both maximums occurred in the 2010-2011 crop year.

Given that the analysis is for the state of Illinois, demand for storage space is composed almost entirely of corn, soybeans, and wheat in storage from prior harvest plus production from the current crop year. Given a harvest date of the second Thursday of October, the latest available information on stocks are from *Grain Stocks* report released by USDA, NASS at the end of September. Information on stocks are as of September 1 and reflect stocks of corn and soybeans from prior crop years (*i.e.*, old crop stocks) plus wheat from both prior and the current crop year, which was harvested earlier in the summer. The latest USDA, NASS report on production of corn and soybeans for the current year would either be in September or October depending on when the second Thursday of October falls relative to the crop production report for October. The sum of these stock and projected production variables, adjusted[7] to a corn bushel basis, averaged 2.4 billion bushels with a range of 1.8 (2012-2013 crop year) to 3.1 (2007-2008 crop year) billion bushels. The individual components are also reported in Table 1.

Supply of storage space is from the annual survey by USDA, NASS of storage capacity that exists both on-farm and off-farm storage capacity. Storage capacity is enumerated as of December 1 and obtained from the January *Grain Stocks* report of the following calendar year. The latest storage capacity report as of the initial storage date of the second Thursday of October would be for December 1 of the preceding calendar years. Storage capacity as of December 1 averaged 2.5 billion bushels and was almost evenly split between on-farm and off-farm locations (see Table 1). USDA did not issue its first storage capacity report until December 1, 1988, which is the reason this analysis does not begin until the 1989-1990 crop year.

The ratio of demand to supply of storage space, designated $STORCAP$, averaged 98 percent. $STORCAP$ ranged from 63 percent (2012-2013 crop year) to 120 percent (2007-2008 crop year). The crop years were almost evenly divided into years in which demand for storage space was higher and lower than the supply of storage space. The ratio was less than 90 percent in 8 crop years and greater than 110 percent in five

[6]USDA, NASS explains the survey procedure, “most reporters complete their questionnaire on Friday or early Monday morning and submit it to the NASS Field Office in their State ... Regardless of the time that the questionnaire is completed, reporters are asked to report for the week ending on Sunday.”

[7]Because a bushel of corn weighs 56 pounds and a bushel of soybeans and wheat weighs 60 pounds, stocks and production are converted to a corn basis by multiplying soybean and wheat bushels by 0.933 (56/60).

crop years.

Because corn and soybeans in Illinois are rotational crops grown at the same time, the unobserved heterogeneity determining net storage return could be correlated across the crops. Statistically significant cross-equation correlation was found by Kim, Zulauf, and Roberts (2014) in their study of returns to storing Illinois corn and soybeans. In this study of returns to storing Illinois corn and soybeans, the correlations[8] average 0.51 for hedged storage and 0.55 for unhedged storage. The Breusch-Pagan test for no contemporaneous cross-equation correlations in disturbances rejects the null hypothesis of no correlation at the one percent significance level. Following the suggestion of Kahl and Tomek (1986), Seemingly Unrelated Regressions (SUR; Zellner, 1962) is chosen over pooled regression and equation-by-equation Ordinary Least Squares (OLS). SUR approach captures the cross equations correlations and thus provides more efficient estimates.

To exam whether the ability to predict net returns to storage is heterogeneous across the seven Illinois production regions, a fixed effects panel (FEP) estimation approach is used for each crop. Thus, as a summary of this section, the following FEP-SUR model is estimated for hedged[9] storage (expressed by superscript HS):

$$\begin{aligned}
AR^{HS}_{c,i,t} =& \alpha_{c,0} + \alpha_{c,1} \times ER_{c,i,t} + \alpha_{c,2} \times HPR_{c,t} + \alpha_{c,3} \times STORCAP_t \\
&+ \sum_{i=2}^{7} \beta_{c,i} \times R_i + \sum_{i=2}^{7} \gamma_{c,i} \times R_i \times ER_{c,i,t} + \varepsilon_{c,i,t} \\
AR^{HS}_{s,i,t} =& \alpha_{s,0} + \alpha_{s,1} \times ER_{s,i,t} + \alpha_{s,2} \times HPR_{s,t} + \alpha_{s,3} \times STORCAP_t \\
&+ \sum_{i=2}^{7} \beta_{s,i} \times R_i + \sum_{i=2}^{7} \gamma_{s,i} \times R_i \times ER_{s,i,t} + \varepsilon_{s,i,t}
\end{aligned} \tag{4}$$

where AR is the actual observed percent net return to storage from the harvest date of the Second Thursday of October until the second Thursday of July, ER is the expected percent net return to hedge storage as of the Second Thursday of October over the storage period, c and s represent corn and soybeans, respectively, HPR is harvest progress rate, $STORCAP$ is the ratio of demand to supply of Illinois storage capacity, R_i = dummy variable for region i, $\boldsymbol{\varepsilon}$ = idiosyncratic disturbance, and $(\boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma})$ are coefficients to estimate.

Given the times series nature of the data, stationarity of the variables used in the regression analysis was checked. Both the Augmented Dickey-Fuller (ADF) test and Phillips-Perron test reject the null hypothesis of non-stationarity (*i.e.* unit root) for all these variables at least at the five percent significance level. Various panel-

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

[9]A similar FEP-SUR model is separately estimated for unhedged storage.

data unit-root tests including the Levin-Lin-Chu test and Im-Pesaran-Shin test also supported stationarity of the variables.[10]

3.3 Findings

Expected net return to hedged storage across all years (ER) was negative for each of the seven Illinois regions over the 1988-2012 crop years for both corn (see Table 2) and soybeans (see Table 3). Actual net return (AR) averaged across all years was higher than ER for each region and crop only for unhedged storage. Moreover, average AR was higher for unhedged than hedged storage. Standard deviation of the annual ARs was much higher for unhedged than hedged storage: across all seven regions, standard deviation averaged 30.1 percent vs. 6.2 percent for unhedged and hedged corn, respectively, and 21.0 percent vs. 3.7 percent for unhedged and hedged soybeans, respectively. These findings are consistent with the classic relationship in finance that higher returns are possible only with higher risk and with previous studies of net storage return.

The variation across years in net return to storage in Illinois is striking, especially for unhedged storage. The range, averaged over the seven Illinois regions, was, for hedged corn, −15.0 to 8.4 percent; for unhedged corn, −34.4 to 107.8 percent; for hedged soybeans, −12.1 to 3.9 percent; and for unhedged soybeans, −27.8 to 65.2 percent. This variation implies that sizable benefits are possible if net storage returns can be predicted successfully.

Results from the FEP-SUR regressions are presented in Table 4 for net hedged storage returns and Table 5 for net unhedged storage returns. The first set of column results in both tables do not include HPR and $STORCAP$. Expected net return to hedged storage is the only explanatory variable significantly associated with actual net return to hedged storage at the 10 percent statistical test level (see Table 4). In contrast, for unhedged storage no explanatory variable, including expected net return to hedged storage, is significant at the 10 percent test level (see Table 5). The test for expected net return to hedged storage is one tailed because a positive relationship is expected from the previous literature, including Working's conceptual arguments. Moreover, R^2 varied notably for the hedged vs. unhedged storage regressions: 0.59 vs. 0.03 for corn and 0.65 vs. 0.00 for soybeans. Last, no statistically significant heterogeneity is found by region for either hedged or unhedged storage.

The second set of column results in Tables 4 and 5 include HPR and $STORCAP$ in the FEP-SUR regressions. Using a two-tail test for HPR and one-tail test for $STORCAP$ based on the discussions above, neither variable is statistically significant at the 10 percent test level in the regression analysis of net hedged storage return. In

[10]The ADF tests with and without trend, drift, and/or lags are conducted.

contrast, both variables are statistically significant at the one percent test level for the regression analysis of net unhedged storage return. Adding HPR and $STORCAP$ increases R^2 for net unhedged storage return from 0.03 to 0.21 for corn and from 0.00 to 0.38 for soybeans.[11] Moreover, adding them does not change either of these two findings when they are not included: (1) expected net return to hedged storage is statistically significant for hedged storage but statistically insignificant for unhedged storage and (2) no statistically significant heterogeneity is found by region.

3.4 Return and Risk Performance of Storage Strategies

Given the results from the FEP-SUR estimations, a HPR and $STORCAP$ based storage signal is created to examine whether their statistically significant coefficients can be translated into a profitable storage signal. The storage strategy evaluated for HPR, hereafter called "the HPR strategy," is to store only when the harvest progress rate exceeds the Olympic moving average[12] of the progress rates for the previous 5 harvests. Thus, the HPR strategy compares current year's progress to a measure of historical normal progress. The storage strategy evaluated for $STORCAP$, hereafter called "the $STORCAP$ strategy," is to store only when demand for storage bin space exceeds supply of storage bin space, or when $STORCAP$ exceeds one. We also examine a combined HPR and $STORCAP$ strategy to assess if the two strategies interact with each other. Specifically, storage is undertaken only when both the HPR strategy and $STORCAP$ strategy signal storage.[13] Return and risk of these various strategies are compared against the return and risk of the basis strategy and the strategy of routinely storing each year.[14]

A key decision in assessing strategies that selectively decide in which years to store is what return should be used for years in which the strategy's signal is to sell at harvest. When the commodity is sold at harvest, the gross return can be used to earn interest income or to pay off existing loans. We thus decided that the appropriate net return in a year in which storage is not undertaken is the opportunity of selling at harvest for that crop year. In this study, opportunity cost is measured using the bank prime loan rate.

[11] The Pearson correlation between HPR and $STORCAP$ is +0.10 for corn and +0.15 for soybeans, which suggests the two variables are not bivariate collinear.

[12] An Olympic moving average limits the impact of outliers since it excludes the highest and lowest values.

[13] Other combinations of the basis, HPR, and $STORCAP$ strategies were examined. Other than the combined $HPR - STORCAP$ strategy, none of the combined strategies improved return or lowered risk more than the individual storage strategies.

[14] Statistical tests of the means and standard deviations, including t-test, F-test, nonparametric sign-rank test, and Levene's test, have low power given the small sample size of the analysis. Hence, they are not conducted. Bootstrapping could be a further option to improve the power of these tests.

For hedged storage, the basis strategy generally dominated the other strategies. Relative to routine hedged storage, it improved net return to storage for each Illinois region and from -3.9 percent to 4.0 percent on average across the seven Illinois regions. It also generally reduced the standard deviation of net return relative to routine hedged storage. Moreover, excluding the Wabash and Little Egypt regions for the basis strategy vs. the combined $HPR - STORCAP$ strategy for corn, the basis strategy had the highest average net return to storage and lowest standard deviation of net return to storage. This finding was not unexpected given the lack of statistical significance of HPR and $STORCAP$ in the regression analysis of actual net return to hedged storage.

For unhedged storage, the HPR, $STORCAP$, and $HPR - STORCAP$ storage strategies dominated routine unhedged storage as they had higher average net returns and lower standard deviation of net returns for all regions and both crops (see Tables 6 and 7). The relationship between these three storage strategies and the basis strategy for unhedged storage is mixed and thus more complex to summarize. The basis strategy generally had a lower standard deviation and often by a sizable amount. The basis strategy had a lower net return for soybean net unhedged return. The highest net return to storage for corn and unhedged storage varied across strategy for different regions.

3.5 Sensitivity Checks

Several sensitivity checks were conducted to assess the robustness of the empirical findings. One involved selling an equal share of the stored crops each Thursday of the storage period, beginning with the second Thursday of October and ending with the first Thursday in July[15]. Other sensitivity checks included using a dollar, instead of percent, measure of net return to storage, using pooled OLS estimations for corn and soybeans instead of the FEP-SUR estimation approach, and using four and five year moving averages instead of three year moving average to estimate expected July basis levels. These sensitivity checks produced results consistent with the results reported in this article.

4 Conclusions and Implications

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 until the

[15]Using the average length of this storage period of 38 weeks, the multiple-sale marketing strategy sells 2.6 percent (= 100% / 38 weeks) of stored stocks each week.

next harvest. Working (1953) suggested the basis strategy could be a profitable strategy to select in which years to store and not store, but empirical studies of its performance provide an inconclusive picture of its effectiveness, especially for unhedged storage. Moreover, available evidence suggests farmers infrequently use hedging with futures contract (Brorsen, 1995; Collins, 1997; Carter, 1999; Pannell et al., 2008).

This study therefore investigates whether other variables can add to the explanation of observed returns to hedged and unhedged storage by expected net return to hedge storage. The analysis uses data for the 1988-2012 crops of Illinois corn and soybeans. Both the rate of harvest progress and the ratio of a demand to supply for storage bin space are found to significantly add explanatory power for unhedged storage, but neither variable is statistically significant in regard to hedged storage net return.

Given the regression results, storage strategies based on harvest progress and ratio of demand to supply for storage bin space are examined. These strategies do not improve upon the return or risk performance of the basis strategy for hedged storage. These strategies do improve upon the return and risk performance of routine unhedged storage but the performance relative to the basis strategy for unhedged storage is mixed and thus inconclusive.

Comparing the best performing strategy for hedged storage, the basis strategy, with the alternative selective storage strategies for unhedged storage, reveals a situation consistent with the classic principle of finance that higher return is associated with higher risk. The basis strategy in combination with hedged storage has both a lower net return to storage and a lower standard deviation of net return. This situation is consistent with the often-made observation that hedging with futures contract is not a dominant practice for farmers (Brorsen, 1995; Collins, 1997; Carter, 1999; Pannell et al., 2008). In other words, the use of hedge storage depends on an individual storage agent's risk aversion and trade-off between return and risk.

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Table 1: Descriptive Statistics, Illinois Corn and Soybeans, 1988-2012 Crop Years

Variable (unit)	Obs.	Mean	S.D.	Min.	Max.
Illinois Stocks as of September 1					
Corn (million bushel)	25	236.7	136.6	63.0	777.0
Soybeans (million bushel)	25	42.0	19.5	16.5	96.6
Wheat (million bushel)	25	40.7	11.8	16.4	61.3
Expected Illinois Production					
Corn (million bushel)	25	1602.5	375.4	665.0	2340.0
Soybeans (million bushel)	25	408.3	63.2	234.9	512.6
Illinois Demand for Storage Bin (million bushel)	25	2388.0	374.0	1828.0	3078.8
Illinois Supply of Storage Bin as of December 1					
On-Farm (million bushel)	24	1270.4	96.8	1150.0	1460.0
Off-Farm (million bushel)	24	1195.3	109.6	1069.3	1451.0
Total (million bushel)	24	2465.7	199.6	2269.3	2911.0
Demand-Supply Ratio of Storage Bin (%)	25	97.7	14.2	62.8	119.9
Harvest Completion Rate (%)					
Corn	25	41.5	25.4	5.0	87.0
Soybeans	25	48.2	18.4	6.0	79.0
Interest Rate (%/year)	25	6.6	2.4	3.3	11.5
Physical Storage Rate ($/year/bushel)	25	0.39	0.08	0.33	0.60

Source: original calculation using data from USDA *Crop Production* report, USDA CCC, USDA *Grain Stocks* report, Federal Reserve Economic Data, USDA *Weekly Weather and Crop Bulletin*, Chicago Mercantile Exchange, Illinois Department of Agriculture

Table 2: Descriptive Statistics, Expected and Actual Net Return to Storage as Percent of Harvest Cash Price by Region, One-Time-Sale Marketing Strategy, Illinois Corn, 1988-2012 Crop Years

Region	Variable	Obs.	Mean	S.D.	Min.	Max.
Northern	Expected Net Return	25	-5.3%	6.2%	-16.4%	5.9%
	Actual Net Return					
	Hedged Storage	25	-5.8%	5.5%	-16.4%	6.8%
	Unhedged Storage	25	-2.6%	30.8%	-36.8%	109.4%
Western	Expected Net Return	25	-5.0%	6.2%	-17.2%	4.8%
	Actual Net Return					
	Hedged Storage	25	-5.3%	5.5%	-16.3%	5.5%
	Unhedged Storage	25	-2.1%	30.6%	-36.7%	108.2%
North Central	Expected Net Return	25	-5.6%	5.6%	-16.8%	2.2%
	Actual Net Return					
	Hedged Storage	25	-5.7%	4.9%	-14.5%	2.2%
	Unhedged Storage	25	-2.6%	30.6%	-34.2%	110.5%
South Central	Expected Net Return	25	-5.2%	5.9%	-14.8%	6.1%
	Actual Net Return					
	Hedged Storage	25	-5.2%	5.9%	-16.1%	5.4%
	Unhedged Storage	25	-2.2%	30.1%	-33.9%	107.9%
Wabash	Expected Net Return	25	-0.8%	9.0%	-14.5%	21.2%
	Actual Net Return					
	Hedged Storage	25	-0.9%	7.4%	-12.5%	13.3%
	Unhedged Storage	25	2.1%	30.1%	-32.1%	109.3%
West Southwestern	Expected Net Return	25	-3.2%	7.8%	-13.8%	20.1%
	Actual Net Return					
	Hedged Storage	25	-3.3%	6.8%	-15.1%	11.3%
	Unhedged Storage	25	-0.5%	29.0%	-35.3%	101.1%
Little Egypt	Expected Net Return	25	-1.3%	8.7%	-12.7%	22.0%
	Actual Net Return					
	Hedged Storage	25	-1.2%	7.7%	-14.4%	14.5%
	Unhedged Storage	25	1.8%	29.6%	-31.8%	108.2%

Source: original calculation using data from USDA *Crop Production* report, USDA CCC, USDA *Grain Stocks* report, Federal Reserve Economic Data, USDA *Weekly Weather and Crop Bulletin*, Chicago Mercantile Exchange, Illinois Department of Agriculture

Table 3: Descriptive Statistics, Expected and Actual Net Return to Storage as Percent of Harvest Cash Price by Region, One-Time-Sale Marketing Strategy, Illinois Soybeans, 1988-2012 Crop Years

Region	Variable	Obs.	Mean	S.D.	Min.	Max.
Northern	Expected Net Return	25	-4.1%	3.0%	-10.6%	2.5%
	Actual Net Return					
	Hedged Storage	25	-4.2%	3.9%	-11.9%	4.5%
	Unhedged Storage	25	6.4%	21.1%	-28.5%	63.7%
Western	Expected Net Return	25	-3.9%	3.1%	-10.1%	2.9%
	Actual Net Return					
	Hedged Storage	25	-4.0%	3.7%	-11.6%	4.8%
	Unhedged Storage	25	6.7%	21.3%	-28.6%	67.1%
North Central	Expected Net Return	25	-4.0%	3.2%	-11.3%	1.9%
	Actual Net Return					
	Hedged Storage	25	-3.9%	3.6%	-12.5%	3.6%
	Unhedged Storage	25	6.6%	21.2%	-28.5%	65.2%
South Central	Expected Net Return	25	-3.9%	3.2%	-11.5%	2.7%
	Actual Net Return					
	Hedged Storage	25	-4.0%	3.6%	-13.6%	4.1%
	Unhedged Storage	25	6.5%	20.8%	-29.3%	65.0%
Wabash	Expected Net Return	25	-2.7%	3.6%	-11.1%	3.6%
	Actual Net Return					
	Hedged Storage	25	-2.9%	3.9%	-13.8%	3.7%
	Unhedged Storage	25	7.7%	20.7%	-26.2%	65.4%
West Southwestern	Expected Net Return	25	-3.4%	3.5%	-10.2%	5.6%
	Actual Net Return					
	Hedged Storage	25	-3.4%	3.9%	-11.2%	3.0%
	Unhedged Storage	25	7.1%	20.7%	-27.4%	64.8%
Little Egypt	Expected Net Return	25	-2.5%	3.8%	-11.1%	4.4%
	Actual Net Return					
	Hedged Storage	25	-2.7%	3.6%	-10.4%	3.6%
	Unhedged Storage	25	7.9%	21.0%	-25.8%	64.9%

Source: original calculation using data from USDA *Crop Production* report, USDA CCC, USDA *Grain Stocks* report, Federal Reserve Economic Data, USDA *Weekly Weather and Crop Bulletin*, Chicago Mercantile Exchange, Illinois Department of Agriculture

Table 4: FEP-SUR Estimation, Hedged Storage, One-Time-Sale Marketing, Percent Storage Return, Illinois Corn and Soybeans, 1988-2012 Crop Years

	Actual Percent Return to Hedged Storage			
Variable	Corn (I)	Soybeans (I)	Corn (II)	Soybeans (II)
Expected Net Return to Storage^A	0.649***	0.948***	0.644***	1.038***
$(= ER)$	(0.129)	(0.140)	(0.141)	(0.133)
Harvest Progress Rate			0.010	0.005
			(0.013)	(0.009)
Demand-Supply Ratio of Storage Bin^A			-0.051	-0.078
			(0.029)	(0.012)
Western Region Dummy	-0.001	-0.002	-0.001	-0.001
$(= R2)$	(0.015)	(0.010)	(0.015)	(0.009)
North Central Region Dummy	-0.001	0.002	-0.000	0.003
$(= R3)$	(0.015)	(0.010)	(0.016)	(0.009)
South Central Region Dummy	0.011	-0.002	0.011	-0.002
$(= R4)$	(0.015)	(0.010)	(0.015)	(0.009)
Wabash Region Dummy	0.020	0.000	0.019	-0.001
$(= R5)$	(0.013)	(0.009)	(0.014)	(0.008)
West Southwestern Region Dummy	0.012	0.001	0.013	0.001
$(= R6)$	(0.014)	(0.009)	(0.014)	(0.008)
Little Egypt Region Dummy	0.021	-0.003	0.021	-0.004
$(= R7)$	(0.013)	(0.009)	(0.014)	(0.008)
$ER \times R2$	-0.068	-0.062	-0.061	-0.029
	(0.182)	(0.194)	(0.191)	(0.182)
$ER \times R3$	-0.059	0.007	-0.054	0.045
	(0.191)	(0.193)	(0.200)	(0.183)
$ER \times R4$	0.124	-0.057	0.143	-0.019
	(0.186)	(0.192)	(0.197)	(0.182)
$ER \times R5$	0.048	0.011	0.058	0.039
	(0.156)	(0.183)	(0.163)	(0.171)
$ER \times R6$	0.048	-0.036	0.070	-0.016
	(0.165)	(0.185)	(0.172)	(0.173)
$ER \times R7$	0.089	-0.128	0.101	-0.120
	(0.158)	(0.180)	(0.165)	(0.168)
Intercept	-0.023**	-0.003	0.023	0.074***
	(0.011)	(0.007)	(0.033)	(0.015)
Number of Observations	168	168	168	168
R^{2B}	0.59	0.65	0.60	0.72

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, Standard errors reported in parentheses. A. One-tailed $t-$tests are implemented given positive sign is expected. B. R^2 is reported from OLS estimations.

Source: original calculation using data from USDA *Crop Production* report, USDA CCC, USDA *Grain Stocks* report, Federal Reserve Economic Data, USDA *Weekly Weather and Crop Bulletin*, Chicago Mercantile Exchange, Illinois Department of Agriculture

Table 5: FEP-SUR Estimation, Unhedged Storage, One-Time-Sale Marketing, Percent Storage Return, Illinois Corn and Soybeans, 1988-2012 Crop Years

	Actual Percent Return to Hedged Storage			
Variable	Corn (I)	Soybeans (I)	Corn (II)	Soybeans (II)
Expected Net Return to Storage[A]	0.283	-0.251	0.004	-1.983
($= ER$)	(0.785)	(1.133)	(0.871)	(1.031)
Harvest Progress Rate			0.346***	0.256***
			(0.080)	(0.070)
Demand-Supply Ratio of Storage Bin[A]			0.539***	0.804***
			(0.184)	(0.095)
Western Region Dummy	0.004	-0.001	0.005	0.000
($= R2$)	(0.100)	(0.086)	(0.096)	(0.072)
North Central Region Dummy	-0.007	0.018	-0.008	0.012
($= R3$)	(0.104)	(0.086)	(0.100)	(0.072)
South Central Region Dummy	-0.002	0.004	-0.001	0.002
($= R4$)	(0.101)	(0.085)	(0.097)	(0.071)
Wabash Region Dummy	0.035	0.025	0.048	0.052
($= R5$)	(0.092)	(0.079)	(0.088)	(0.065)
West Southwestern Region Dummy	0.009	0.006	0.012	0.018
($= R6$)	(0.095)	(0.082)	(0.090)	(0.068)
Little Egypt Region Dummy	0.034	0.024	0.045	0.053
($= R7$)	(0.092)	(0.078)	(0.088)	(0.065)
$ER \times R2$	-0.020	-0.101	-0.030	-0.205
	(1.121)	(1.593)	(1.187)	(1.420)
$ER \times R3$	-0.142	0.388	-0.166	0.138
	(1.171)	(1.573)	(1.237)	(1.424)
$ER \times R4$	-0.117	0.077	-0.106	-0.131
	(1.138)	(1.565)	(1.215)	(1.411)
$ER \times R5$	-0.007	0.339	0.047	0.429
	(0.949)	(1.485)	(1.005)	(1.330)
$ER \times R6$	-0.213	-0.080	-0.342	-0.144
	(1.025)	(1.529)	(1.072)	(1.351)
$ER \times R7$	0.010	0.206	-0.082	0.229
	(0.973)	(1.471)	(1.024)	(1.308)
Intercept	-0.011	0.054	-0.686***	-0.913***
	(0.071)	(0.062)	(0.208)	(0.117)
Number of Observations	168	168	168	168
R^{2B}	0.03	0.00	0.21	0.38

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, Standard errors reported in parentheses. A. One-tailed $t-$tests are implemented given positive sign is expected. B. R^2 is reported from OLS estimations.

Source: original calculation using data from USDA *Crop Production* report, USDA CCC, USDA *Grain Stocks* report, Federal Reserve Economic Data, USDA *Weekly Weather and Crop Bulletin*, Chicago Mercantile Exchange, Illinois Department of Agriculture

Table 6: Return Performance of Basis Strategy and Alternative Storage Strategies, One-Time-Sale Marketing, Percent Net Return to Storage, Illinois Corn and Soybeans, 1988-2012 Crop Years

	Average Percent Return to Hedged Storage					Average Percent Return to Unhedged Storage				
Region	Routine	Basis	HPR	STORCAP	HPR STORCAP	Routine	Basis	HPR	STORCAP	HPR STORCAP
	Illinois Corn									
Northern	-5.8%	3.7%	-0.4%	0.5%	1.7%	-2.6%	1.7%	6.0%	2.4%	5.8%
Western	-5.3%	2.8%	-0.1%	0.8%	1.9%	-2.1%	7.6%	6.4%	2.8%	6.1%
N. Central	-5.7%	2.9%	-0.2%	0.7%	2.1%	-2.6%	7.8%	6.1%	2.6%	6.2%
S. Central	-5.2%	4.4%	0.3%	1.2%	2.6%	-2.2%	4.1%	6.5%	3.0%	6.6%
Wabash	-0.9%	5.1%	3.1%	4.4%	5.1%	2.1%	6.8%	9.3%	6.3%	9.1%
W. Southwest	-3.3%	4.4%	1.3%	2.5%	3.4%	-0.5%	1.4%	7.4%	4.2%	7.3%
Little Egypt	-1.2%	4.9%	2.8%	4.3%	5.0%	1.8%	6.6%	8.9%	6.2%	9.0%
Average	-3.9%	4.0%	1.0%	2.0%	3.1%	-0.9%	5.1%	7.2%	3.9%	7.2%
	Illinois Soybeans									
Northern	-4.2%	5.1%	0.7%	0.3%	2.1%	6.4%	5.0%	7.4%	8.4%	7.5%
Western	-4.0%	4.8%	1.0%	0.6%	2.5%	6.7%	4.6%	7.8%	8.6%	7.9%
N. Central	-3.9%	5.1%	1.0%	0.9%	2.6%	6.6%	4.9%	7.6%	8.8%	7.9%
S. Central	-4.0%	5.1%	1.2%	0.7%	2.8%	6.5%	4.9%	7.8%	8.6%	8.1%
Wabash	-2.9%	3.9%	1.8%	1.5%	3.2%	7.7%	4.8%	8.5%	9.5%	8.6%
W. Southwest	-3.4%	4.9%	1.4%	1.2%	3.0%	7.1%	4.8%	8.1%	9.1%	8.3%
Little Egypt	-2.7%	4.2%	1.7%	1.7%	3.1%	7.9%	4.2%	8.4%	9.6%	8.5%
Average	-3.6%	4.7%	1.3%	1.0%	2.8%	7.0%	4.7%	7.9%	8.9%	8.1%

Source: original calculation using data from USDA *Crop Production* report, USDA CCC, USDA *Grain Stocks* report, Federal Reserve Economic Data, USDA *Weekly Weather and Crop Bulletin*, Chicago Mercantile Exchange, Illinois Department of Agriculture

Table 7: Risk Performance of Basis Strategy and Alternative Storage Strategies, One-Time-Sale Marketing, Percent Net Return to Storage, Illinois Corn and Soybeans, 1988-2012 Crop Years

	Standard Deviation of Annual Percent Returns to Hedged Storage					Standard Deviation of Annual Percent Returns to Unhedged Storage				
Region	Routine	Basis	HPR	STORCAP	HPR STORCAP	Routine	Basis	HPR	STORCAP	HPR STORCAP
					Illinois Corn					
Northern	5.5%	4.2%	6.5%	6.0%	5.5%	30.8%	9.8%	27.5%	26.5%	24.7%
Western	5.5%	5.3%	6.3%	5.7%	5.3%	30.6%	22.7%	27.2%	26.2%	24.4%
N. Central	4.9%	5.0%	6.1%	5.4%	4.6%	30.6%	23.3%	27.2%	26.8%	24.9%
S. Central	5.9%	3.1%	6.5%	5.7%	4.5%	30.1%	9.2%	26.5%	26.3%	24.3%
Wabash	7.4%	4.2%	6.2%	4.8%	4.0%	30.1%	24.4%	26.0%	25.5%	23.6%
W. Southwest	6.8%	3.4%	6.6%	5.8%	5.0%	29.0%	12.0%	25.2%	24.4%	22.5%
Little Egypt	7.7%	4.3%	6.8%	5.2%	4.3%	29.6%	24.1%	25.7%	25.4%	23.5%
Average	6.2%	4.2%	6.4%	5.5%	4.7%	30.1%	17.9%	26.5%	25.9%	24.0%
					Illinois Soybeans					
Northern	3.9%	1.8%	5.4%	5.5%	4.9%	21.1%	1.9%	15.3%	17.6%	14.1%
Western	3.7%	2.4%	4.9%	5.1%	4.1%	21.3%	2.6%	15.7%	17.8%	14.6%
N. Central	3.6%	1.8%	5.0%	4.8%	4.1%	21.2%	2.0%	15.6%	17.8%	14.4%
S. Central	3.6%	1.8%	4.8%	4.9%	3.7%	20.8%	2.0%	15.4%	17.5%	14.4%
Wabash	3.9%	2.6%	4.2%	4.5%	3.2%	20.7%	8.7%	15.4%	17.4%	14.4%
W. Southwest	3.9%	1.9%	4.6%	4.9%	3.7%	20.7%	2.2%	15.0%	17.1%	13.9%
Little Egypt	3.6%	2.3%	4.3%	4.3%	3.3%	21.0%	8.2%	15.3%	17.5%	14.2%
Average	3.7%	2.1%	4.7%	4.9%	3.8%	21.0%	3.9%	15.4%	17.5%	14.3%

Source: original calculation using data from USDA *Crop Production* report, USDA CCC, USDA *Grain Stocks* report, Federal Reserve Economic Data, USDA *Weekly Weather and Crop Bulletin*, Chicago Mercantile Exchange, Illinois Department of Agriculture