Storage decisions depend upon an individual farmer's cost of storage, aversion to risk and local market conditions. Nevertheless, several general principles exist: (1) returns depend on the time of harvest; (2) hedging generally reduces risk and return; and (3) the basis provides a useful selective storage strategy but only if storage is hedged.

Introduction
The 1996 Farm Bill reduced the level of government support to field crop producers (Nelson and Schertz). As a result, marketing skills are receiving increased attention. Because selling the entire crop before harvest is rare, the most common marketing decision faced by farmers is whether to store or sell at harvest. Heifner (1966); Hoover and Kenyon; Jones; Nefstead; Riggins, Skees and Reed; Tabesh, Schroeder and Starleaf; Tomek, and Working have investigated storage returns for field crops. As a group, these studies have focused on selective storage strategies. The most commonly evaluated selective strategy is a decision rule first documented by Working: Store only when the expected appreciation in the basis exceeds the cost of storage. When used with hedged storage, this strategy generally improved returns and/or reduced the risk (that is, variation) of storage returns (Heifner, 1966; Hoover and Kenyon; Tomek; Working).

Storage decisions and returns depend on an individual producer's cost of storage, aversion to risk and local market conditions. Nevertheless, all farmers should consider three general storage principles when making storage decisions. These principles are derived from the commonly observed behavior of prices, application of economic concepts and previous empirical research. They are: (1) storage returns depend on time of harvest; (2) hedging generally reduces the risk and return to storage; and (3) the basis strategy generally improves returns to hedged storage, but not to unhedged storage. Previous studies have not examined principle 1, and only one study (Heifner, 1966) has examined principle 3.

This study illustrates these general storage principles by examining returns to storing Ohio-produced corn over the 34 years between the 1964-65 crop year and the 1997-98 crop year. This is the longest set of storage data evaluated. As a comparison, the number of years evaluated in previous studies ranged from two years by Jones to 13 years by Heifner (1966). A long data set enhances the statistical power of the analysis, in part because it contains a more diverse set of market and weather conditions. Thus, it is more likely that the data will reveal general principles that apply across a variety of situations.

The general principles of storage are discussed in the next section. Then, the data and procedures used in
this study are discussed, followed by a discussion of the results of the empirical analysis. The final section contains a summary and implications.

**General Storage Principles**

**Principle 1:**
*Storage returns vary by time of harvest.*
Cash prices tend to be high at the beginning of harvest, reach a low around the middle of harvest and then climb as harvest winds down. This well-known "j"-shape" pattern suggests that storage returns depend on the time of harvest, with returns to storage being highest for crops cut near the middle of harvest.

The relevant harvest pace is both the local harvest pace and the national harvest pace. The former affects the local cash price directly while the latter affects the national average price, which, in turn, affects the local cash price. Difference in the average pace of the local and national harvest reflects, in part, how far the local production is from the main production area. In the case of Ohio, corn harvest usually follows the same pace as the national harvest. Therefore, this study does not address the relative importance of local and national harvest pace in determining principle 1. However, it is possible that principle 1 diminishes in importance as the pace of local and national harvest diverges.

**Principle 2: Hedging generally reduces the risk and return to storage.**
A storage hedge involves selling a futures contract in combination with a long cash market position. Because cash and futures prices tend to move in the same direction (that is, be positively correlated), the change in the value of the short futures position should partially offset the change in the value of the long cash position. Hence, returns should vary less for hedged storage than for unhedged storage.

The expected lower risk for hedged storage implies that it should earn a lower return than unhedged storage would. This implication is derived from a key principle of modern finance: Risk and return are positively correlated.

Hedging may not reduce risk if changes in cash and futures prices are not positively correlated. Examples of this situation tend to involve local markets that are geographically far from the futures market and center of production or produce varieties that differ from the variety traded on the futures contract (Heinzer, 1996).

**Principle 3:**
*The basis strategy generally enhances returns to hedged storage, but not to unhedged storage.*

The basis strategy involves comparing the expected appreciation in the basis with the cost of storage over the expected storage period. The expected appreciation in the basis is determined by comparing the current basis with the basis expected at the end of the storage period. Storage should occur only when the expected appreciation in the basis exceeds the variable cost of storage. Otherwise, the crop should be sold.

Returns to unhedged storage are generated by changes in the level of cash prices while returns to hedged storage are generated by changes in the cash price relative to changes in the futures price. Hedged storage can earn positive returns even if the cash price declines, provided the futures price declines more than the cash price declines. Similarly, even if cash price increases, hedged storage can generate a loss if the futures price increases more than the cash price increases.

The basis strategy provides information on the expected change in the cash price relative to the futures price. Thus, the basis strategy should be useful in enhancing returns to hedged storage, but it should provide little useful information for enhancing returns to unhedged storage. The basis strategy also should reduce the risk associated with hedged storage because storage is avoided during years in which hedged storage is expected to generate a loss.

As with principle 2, the applicability of principle 3 depends on the correlation between cash and futures price. Hence, the applicability of principle 3 probably diminishes as the difference between the local cash market and futures market/center of production increases and if the crop variety is not the same as that traded on the futures contract.

**Storage Strategies, Net Return Calculations and Data**
Unhedged storage involves storing the cash commodity without using any non-cash marketing instrument. A long cash market position is taken the day of harvest and is maintained until the cash commodity is sold. The cash price (that is, market) examined in this study is the average state-wide price of corn paid to farmers by elevators in Ohio. These prices were collected for each Tuesday between October 1 and July 7 of the 1964-65 through 1997-98 crop years. Using Tuesday prices avoids (a) most holidays and (b) the price volatility that can occur on Mondays and Fridays in reaction to or anticipation of weekend events.

Sources of the data were the Ohio Department of Agriculture for the period October 1, 1964 - July 1, 1994 and, subsequently, the U.S. Department of Agriculture (USDA)-Illinois Department of...
Agriculture. The data are currently collected by surveying four to six country grain elevators located in each of five regions in Ohio. The survey specifically collects cash bid prices offered to farmers for their grain after trading closes on the Chicago Board of Trade (Illinois Department of Agriculture).

To evaluate returns to hedged storage, a classic storage hedge is used; that is, equal and opposite positions always exist in the cash and futures markets. Specifically at harvest, a short position is taken in the July corn futures contract that matures during the next calendar year. This short position is closed out (that is, bought back) the same day that cash corn is sold. The July contract is used because it is the last consistently old crop contract. The September futures contract may be a new crop contract if harvest starts early enough. Closing futures price on the Chicago Board of Trade July corn contract was collected for each Tuesday from an electronic database compiled by Technical Tools, Inc., and from The Wall Street Journal.

The classic storage hedge requires a minimal amount of information and time to monitor the strategy. More dynamic strategies can be used, such as rolling the storage hedge among different futures contracts. However, returns to dynamic storage strategies include a return to information and analysis of prices and spreads. Using a classic storage hedge simplifies the analysis and focuses it on the return to storage, not the return to analysis and information.

Three harvest dates—the Tuesdays that fell during the weeks when 10 percent, 50 percent and 90 percent of Ohio’s corn crop was harvested—were evaluated. These harvest completion dates varied by year but, on average, fell during the first week of October, the first week of November and the last week of November. The average dates are used instead of the year-specific dates because the storage returns and risk are similar, but they are simpler to present and discuss for the average dates. The reason for the similar returns and risks for the year-specific and average dates is that, for the majority of years, harvest does not vary much from its normal pace in Ohio. Harvest progress is reported in the Weekly Weather and Crop Bulletin, a joint publication of the U.S. Departments of Commerce and Agriculture.

Each storage period began on the Tuesday of harvest. Ending dates increased at weekly intervals, starting with the second Tuesday after harvest and ending with the first Tuesday in July. Thus, the first storage period was from the week of harvest to the next week; the second storage period was from the week of harvest to the Tuesday two weeks after harvest, etc.

There were 31, 34, and 39 storage periods for late-harvested corn (90 percent of Ohio’s harvest completed), mid-harvested corn (50 percent of Ohio’s harvest completed) and early-harvested corn (10 percent of Ohio’s harvest completed), respectively.

This study examines storage from the perspective of off-farm storage. Relevant costs in this situation are interest opportunity cost and the physical storage costs charged by elevators. These costs are incurred by both unhedged and hedged storage. Hedged storage also incurs the costs associated with trading futures contracts.

Interest opportunity cost arises because, instead of storing the crop, the crop can be sold at harvest. Proceeds from selling at harvest can be used to pay off debt or to earn interest income. Interest opportunity cost was calculated as the simple interest earned between harvest and the date of cash sale. A key decision is what interest rate to use in calculating interest opportunity cost. It can vary from the passbook savings rate to the rate on operating or ownership loans. When analyzing storage decisions, the specific rate depends on how the farmer would use the income from selling at harvest. For this study, the prime interest rate was used because it falls between saving and lending rates.

The prime rate was collected from the Federal Reserve Bulletin. It varied from 5.0 percent (1964-65 crop year) to 19.5 percent (1981-82 crop year).

Physical storage cost is what an elevator charges a farmer to store a commodity. The only series of physical storage rates consistently available over the analysis period are the rates paid by USDA to elevators for storing government-owned corn (Engle). USDA storage rates are reported as a flat rate for a year and are averages for the United States. They varied from 13.14 cents per bushel (1964-65 through 1970-71 crop years) to 34.05 cents per bushel (1987-88 crop years). For this study, the yearly rate was converted to a daily rate based on 365 days/year.

Limitations exist in using USDA storage rates. USDA may be able to extract volume or length of storage discounts; thus, its storage rate may be less than the rate paid by farmers. Furthermore, off-farm storage rates paid by farmers are not always a constant daily rate. In particular, the storage rate may be higher during the first few months of the storage season (see Good et al. for a specific example).

While these limitations need to be kept in mind, their impact on this study is minimized by this study’s focus on comparing returns among different harvest dates and between hedged and unhedged storage.
Each alternative being compared uses the same physical storage rate. Thus, each alternative would be affected similarly if a different physical storage rate were used, resulting in little impact on the qualitative nature of the results of this study.

Costs of trading futures contracts include brokerage fees and liquidity costs. Currently, brokerage fees are commonly cited as $50 for a round-trip trade (that is, buying and selling) of a 5,000-bushel futures contract (Good et al.). To create a historical time series, the current brokerage fee was deflated for earlier years using the consumer price index.

Liquidity costs are payments earned by floor traders (scalpers) for filling an order for immediate execution at the market price. They are incurred each time a futures contract is traded. Liquidity costs for grain futures markets are estimated to be one price tick for the more heavily traded nearby contracts and two price ticks for the more lightly traded contracts that are more than five months from delivery (Brosen; Thompson and Waller). The minimum price tick for corn is currently .25 cents per bushel. Before 1973, it was .125 cents per bushel. Using the current minimum price tick, liquidity costs were estimated as $50 per 5,000-bushel contract for a harvest-time hedge lifted before February 1 and $37.50 for a hedge lifted after February 1.

To summarize this section, net storage returns were calculated as follows:

1. **NET RETURN TO UNHEDGED STORAGE** = 
   Cash Price When Sold - Cash Price at Harvest - 
   Interest Opportunity Cost between Harvest and Date of Cash Sale - Physical Storage Cost between Harvest and Date of Cash Sale.

2. **NET RETURN TO HEDGED STORAGE** = 
   Net Return to Unhedged Storage (from equation 1) + Price July Corn Futures is Sold at Harvest - Price July Corn Futures is Bought Back - Futures Trading Cost.

**Findings**

**Principle 1:**

*Storage returns vary by time of harvest.*

Returns to both unhedged and hedge storage were greater at the 50 percent harvest completion date than they were at the 10 percent and 90 percent harvest dates (see Figures 1 and 2). For the 50 percent harvest completion date, average net returns to unhedged storage generally were 4-7 cents per bushel while net returns to hedged storage generally averaged 2-5 cents per bushel. In contrast, regardless of the length of storage, average net returns generally were negative for hedged storage at the 10 percent
and 90 percent harvest completion dates and for unhedged storage at the 10 percent harvest date. Average net returns to unhedged storage at the 90 percent harvest completion date generally were positive but close to zero.

An important marketing management tool is to test for statistical significance. This provides an indication of whether historical differences may be due to random chance. Historical differences not due to random chance are more likely to continue to exist in the future. Two critical assumptions are made when conducting the statistical tests on net storage returns. One is that an adequate number of observations exist to fully specify the distribution of net returns to storage. The number of observations in this study is large compared to other storage studies but is not large relative to the desired number of observations from statistical sampling theory. The second is that no major change will occur in the market that will affect the future distribution of net returns. Both assumptions should be kept in mind when considering the following discussion.

Statistical tests were conducted to determine whether net storage returns at the 50 percent harvest completion date were greater than net storage returns at the 10 percent and 90 percent harvest dates. At the commonly used 95 percent confidence test level, net returns to hedged storage at the 50 percent harvest completion date were significantly greater than the net returns to hedged storage at the 10 percent and 90 percent harvest dates for all weekly storage periods. The same result was found for unhedged storage at the 50 percent harvest completion date relative to the 10 percent harvest completion date. In contrast, for only one-third of the weekly storage periods did the net returns to unhedged storage at the 50 percent harvest completion date significantly exceed net returns at the 90 percent harvest date. Nevertheless, taken as a whole, this statistical evidence is consistent with storage principle 1.

Principle 2: Hedging generally reduces the risk and return to storage.

A common measure of storage return risk is the standard deviation of returns. This measure is presented in Figures 3 and 4. The standard deviation of unhedged storage returns is always greater than the standard deviation of hedged storage returns, regardless of the time of harvest or the length of the storage period. The risk reduction effect of hedged storage becomes more pronounced the longer the storage period. Using the 95 percent confidence level, the standard deviation of hedged storage was significantly less than the standard deviation of unhedged storage, except for only a few storage periods of less than two months in length.

![Figure 3. Return Risk of Unhedged Storage by Time of Harvest and Week Sold After Harvest, Ohio Corn, 1964-1997 Crop Years](image)

![Figure 4. Return Risk of Hedged Storage by Time of Harvest and Week Sold After Harvest, Ohio Corn, 1964-1997 Crop Years](image)
As expected from the modern theory of finance, the lower risk of hedged storage relative to unhedged storage is associated with a lower return for hedged than for unhedged storage at the 50 percent and 90 percent harvest completion dates (see figures 1 and 2). In contrast, net storage returns are similar for hedged and unhedged storage at the 10 percent harvest completion dates. One reason that net returns to hedged storage should be lower than the returns to unhedged storage is the cost of trading futures contracts.

The above results imply that, when evaluating unhedged versus hedged storage, it is important for a producer to evaluate his/her trade-off between risk and return. A critical factor in this trade-off is the producer's attitude toward risk. The more risk-adverse the producer, the more willing s/he will be to hedge storage. Similarly, the more risk the producer is willing to take on, the more willing s/he will be to store unhedged.

*Principle 3:*

The basis strategy generally enhances returns to hedged storage, but not to unhedged storage.

The basis storage strategy was implemented as: Store Only If [cash basis at harvest - cash basis expected to exist the first Tuesday of next July] > [storage costs until next July]. The calculation involves subtraction because the basis was defined as futures price minus cash price. The first term contained within brackets represents the expected appreciation in the basis between harvest and next July. The basis expected to exist next July is calculated as the average of the three most recent bases observed on the first Tuesday of July. While disagreement exists about the optimum number of years to include in calculating it, the simple moving average compares favorably with more sophisticated forecasting techniques in terms of accuracy in forecasting the basis for crops (see Dhuyvetter and Kastens, and the literature cited therein).

To illustrate the implementation of the basis strategy, consider the following data for the 10 percent harvest completion date during the 1980 crop year. On October 7, 1980, the July 1981 corn futures quote minus the cash corn price quoted for Ohio was 64 cents per bushel. The basis expected for the beginning of July 1981 was 20 cents per bushel, based on the average of the July futures—cash basis observed on the first Tuesday of July 1978, 1979 and 1980. Storage costs from October 7, 1980, to the first week of July 1981 were estimated at 53 cents per bushel. Inserting these numbers into the basis storage equation results in an expected basis appreciation of 41 cents per bushel (64 cents - 20 cents), which is less than the 53 cents to store a bushel of corn. Hence, the basis strategy indicates that corn should not be stored.

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**Figure 5. Average Net Return to Unhedged Storage Strategies by Week Sold After Harvest, 50% Harvest, Ohio Corn, 1967-1997 Crop Years**

**Figure 6. Average Net Return to Hedged Storage Strategies by Week Sold After Harvest, 50% Harvest, Ohio Corn, 1967-1997 Crop Years**
in 1980 to avoid a projected loss of 9 cents per bushel.

The basis strategy indicated that corn cut at the 50 percent harvest completion date should have been stored in 17 years and not stored in 14 years. At the 10 percent and 90 percent harvest completion dates, the basis strategy signaled storage in 11 years and 10 years, respectively. Due to concerns about space, the remaining discussion focuses on the 50 percent harvest completion date. In general, the same results are found for the 10 percent and 90 percent harvest completion dates.

The net returns for routine unhedged storage and unhedged storage using the basis strategy are presented in Figure 5 while the net returns for routine hedged storage and hedged storage using the basis strategy are presented in Figure 6. For the basis strategy, net storage returns were recorded as zero for years when the basis strategy indicated that storage should not be undertaken. By default, storage returns were zero for that year because no storage was undertaken. Note that the 1964–65, 1965–66 and 1966–67 crop years were not included in this analysis because three years of data did not exist with which to calculate the expected basis.

Comparison of Figures 5 and 6 reveals that, relative to routine storage, the basis strategy improved returns to hedged storage, but not to unhedged storage. In fact, the basis strategy improved returns to hedged storage enough so that its average net returns were similar to that of routine unhedged storage except for storage until June when routine unhedged storage had a higher net return.

The reason for the different impacts of the basis strategy on hedged and unhedged storage are explored further in Figures 7 and 8. The two lines in each of these graphs represent (1) the set of average net returns that occurred during years when the basis strategy said store and (2) the set of average net returns that occurred during years when the basis strategy said do not store.

For unhedged storage—that is, figure 7—the two sets of returns are nearly the same for both situations and do not differ statistically at the 95 percent confidence level. In other words, the basis strategy did not enhance returns to unhedged storage because it was not able to differentiate between the years when unhedged storage earned positive returns and the years when unhedged storage generated a loss. Heifner (1966) reached a similar conclusion. Inability of the basis strategy to enhance returns to unhedged storage is consistent with the earlier argument that the basis provides information about the change in cash price relative to futures price, not about the change in the level of the cash price.
In contrast, for hedged storage—that is, figure 8—the basis strategy was able to differentiate between the years when hedged storage earned positive returns and, thus, should occur and the years when hedged storage generated a loss and, thus, should not occur. Except for the first week after harvest, net storage returns, when the basis strategy signaled storage, were statistically larger at the 95 percent confidence level than were net storage returns when the basis signaled that the corn should be sold at harvest, that is, not stored.

Given that the basis strategy effectively predicted the years in which hedged storage should occur, it is not surprising that the standard deviation of net returns is lower for hedged storage with the basis strategy than it is for routine hedged storage (see Figure 9). The difference in standard deviation became more pronounced as the length of the storage period increased. Not surprisingly, the incidence of a loss from storage also declined when the basis strategy was used. For storage periods of 10, 20, and 30 weeks, a loss was incurred in only three years when the basis strategy was used with hedged storage. As a comparison, a loss was incurred in at least 10 years for routine hedged storage.

To summarize this section, at the 50 percent harvest completion date for off-farm storage of corn in Ohio over the 1967–97 crop years, hedged storage using the basis strategy was a superior strategy to routine unhedged storage and routine hedged storage for almost all storage periods. Routine unhedged storage and hedged storage using the basis strategy generated similar average net returns, but risk was much lower for hedged storage using the basis strategy.

**Summary**

Evaluation of storage returns and risks depends on the situation confronted by an individual farmer. Important considerations include the cost of storage, aversion to risk and local market conditions. Despite the inherent uniqueness of each storage situation, there are three general principles that farmers and farm managers need to consider when developing storage and marketing plans: (1) Storage returns vary by time of harvest; (2) hedging generally reduces the risk and return to storage; and (3) the basis strategy generally enhances returns to hedged storage, but not to unhedged storage.

Empirical support for these principles are found using data for off-farm storage of corn produced in Ohio over the 34 crop years between 1964–65 and 1997–98. This data set is 21 years longer than is the previous, longest data set used in a study of storage returns. A longer data set enhances statistical confidence in the analysis and the likelihood of finding general principles. It is an open question whether the empirical results of this study will hold for other geographical areas and in the future, but they are consistent with the general storage principles. Thus, they would be expected to hold for the major U.S. corn production region.

The findings of this study underscore the importance of (1) understanding the impact that time of harvest has on storage returns and (2) examining the strategy of using hedged storage in conjunction with the basis to determine whether or not to store. The strategy of using the basis to decide whether or not to store has limited usefulness when making unhedged storage decisions. This part of general storage principle 3 is frequently violated in marketing articles written for the general public.

In conclusion, it is important to understand the local situation when making storage decisions. It is also important to understand the general principles of storage. Understanding both the local situation and the storage principles increases the likelihood of making storage decisions that maximize return while minimizing risk.
Endnotes
1 To examine the sensitivity of this study's findings to alternative interest rates, the short- and intermediate-term non-real-estate interest rate charged by the Farm Credit System and its predecessors was used as an alternative opportunity cost interest rate. Also examined were several fixed percentage point differences from the prime interest rate, such as three percentage points below the prime rate. The general finding is that the level and patterns of net storage returns vary little for the first one to two months of storage, but differences become more pronounced as the storage period lengthens. These results were expected. However, the focus of this study is on comparing net storage returns across harvest completion dates and between hedged and unhedged storage. A change in interest rates generally affects each alternative in the comparison similarly. Thus, the use of an interest rate other than the prime rate does not affect the qualitative results of this study.

2 No opportunity cost charge is made for the margin money required to establish a futures contract position. This opportunity cost is expected to be small for four reasons. (1) The initial margin money is only a small percent of the contract's total value. For example, between 1985 and 1996, the initial margin for a hedge position on a Chicago Board of Trade corn futures contract ranged from $300 to $1,500 but was under $600 most of the time (Alexander). (2) The available evidence suggests that corn futures prices are unbiased forecasts (Zulauf and Irwin). On average, today's quote of a futures contract will equal tomorrow's quote of the contract. Therefore, over time, the average change in margin money should equal zero. (3) The initial margin can be secured as U.S. treasury bills; thus, an opportunity cost should be charged only to the extent that the opportunity cost interest rate exceeds the U.S. treasury rate. (4) The storage periods are less than a year, most considerably less than a year in length. In addition to the expected small average opportunity cost of margin money, a focus of this study is on comparing net storage returns across harvest completion dates. Including an opportunity cost of margin money generally should affect each alternative in the comparison similarly. Thus, omitting this opportunity cost should not alter the qualitative results of this study.

3 An issue is whether net storage returns should be deflated. No straightforward answer exists because the impact of inflation on net storage returns is difficult to disentangle. An important determinant of interest rates is the expected inflation rate. Furthermore, the increase in physical storage rates over time partially reflects inflation. Therefore, the impact of inflation is partially captured in the calculation of net storage returns. Hence, deflating net storage returns will overstate the impact of inflation. After considering the situation, the authors chose not to deflate net storage returns. This decision should be kept in mind when reading the article.

References


