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Accounting for yield risk in preharvest commodity pricing decisions

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Accounting for yield risk in preharvest commodity pricing decisions

by

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CHAPTER 1. INTRODUCTION

Agricultural producers are subject to risk because prices and yields are uncertain. Crop production risk is the result of unpredictable weather patterns which occasionally bring drought, floods, or hail. These occurrences, combined with the normal variability of rainfall and temperature, cause production at the farm level to be very unstable. Price risk results from a combination of production risk and the often unstable demand for agricultural products. Hedging in the futures and options markets allows agricultural producers to adjust their revenue risk and establish favorable prices. The effectiveness of the futures and options markets in offsetting revenue risk, however, is highly dependent on the size of the position taken in these markets and the behavioral relationships between local cash prices and the futures prices and options premiums established on the commodity exchanges.

Research on the appropriate hedge position often addresses only hedges placed after harvest (storage hedges) for grains or oilseeds such as corn, wheat, or soybeans. Many hedging advisors, however, recommend placing hedges prior to harvest. Wisner (1991) has shown preharvest hedging to be a viable means of revenue enhancement when compared to cash sales at harvest. Grant (1987) examined planting time hedges at the county, state, and national level, but did not consider options hedges or use individual farm yield data. Karp (1987) also addressed hedging with stochastic production outcomes, but only included futures markets. Greenhall, Tauer, and Tomek (1984) considered preharvest hedging in the futures market for a variety of hedger objective functions but only analyzed a small number of farms in New York and Illinois.

The objective of this study is to evaluate the risk-return tradeoffs associated with varying levels of preharvest futures or options positions for individual farms. The intent is to determine whether optimum hedge ratios based on county or state yield variability differ from those calculated for individual farms. In addition, previous studies have generally ignored using options as a preharvest hedging tool. The unique characteristics of options seem especially appropriate for dealing with yield risk, and the potential role of options in revenue risk management under conditions of yield uncertainty warrants evaluation.

Since the distribution of returns for commodity options positions are truncated, non-normal distributions, the standard regression approaches to optimum hedge ratio estimation do not apply to options positions. In addition, if price and quantity are correlated, a price risk minimizing futures hedge ratio will differ from the optimum preharvest hedge ratio. Since the quantity estimate and error distribution would be expected to vary as new information changes the estimate of final production, the optimum futures or options position will also change as harvest approaches.

In this study, both the change in the expected yield distribution and the choice of hedging instruments (futures or options) are considered in determining the optimum preharvest hedge ratio for farmers producing corn in Iowa. To evaluate futures and options hedging strategies consistently and account for the interaction between price and quantity, the returns from a wide range of possible hedge ratios for 250 individual farms over a nine year period (1981-1989) are evaluated by numerical simulation. Similar analyses are done using county, state, and national yield data. State and national level optimum hedge ratios are also evaluated for hedges placed at the first of August, when little yield risk remains. Hopefully, this analysis should provide some useful guidelines regarding the risk-return tradeoffs for farmers contemplating preharvest futures or options positions. Further, this analysis should determine whether analysts and risk managers can reasonably apply more aggregate optimum hedge ratio estimates to individual farms and what the risks of using those aggregate hedge ratio estimates might be.

Chapter 2 begins with a discussion of the optimum hedge ratio and a review of the relevant research that has been done in this area. This chapter includes a summary of research on minimizing price risk and minimizing combinations of both price and yield risk. Chapter 3 reviews the price and yield data that were used in this research. The methods used to determine the optimum preharvest futures and options positions are explained in Chapter 4. The results are presented in Chapter 5. Chapter 6 provides the summary, conclusions, and implications of my research.

CHAPTER 2. LITERATURE REVIEW

Defining the Optimum Hedge Ratio

For most purposes, the optimum hedge ratio is defined as the ratio of futures position to cash position that provides the most desirable combination of risk and return for a given individual. The optimal hedge ratio is typically estimated via the minimum risk hedge ratio (McKinnon 1967). The minimum risk hedge ratio is the combination of futures and cash positions that minimizes the variance of revenue generated by the combination of these positions. For the minimum risk hedge ratio to be a valid estimator of the optimal hedge ratio two assumptions must be made. The first assumption is that the expected revenue from the futures position is zero. This assumption implies that the current futures price is an unbiased estimator of the futures price that will prevail when the contract expires. The second assumption is that commission fees, margin deposits, and the interest foregone on margin deposits are equal to zero.

Since these assumptions are probably never perfectly met, it is best to assume that the optimal hedge ratio will probably be slightly different in value than the true minimum risk hedge ratio. Baillie and Myers (1990) found zero expected returns to holding futures in six commodities, including corn, which implies that minimum variance hedge ratio estimates are generally consistent with expected utility maximization. This validates using the simpler and more broadly applicable minimum risk hedge ratios in place of the more complex utility maximizing hedge ratio estimators.

Alternatively, the optimum hedge position could be viewed as a two step process. The first step would be determining whether or not to take a position based on price expectations or risk considerations. The second step would be determining how to achieve the objective reached in the first step most efficiently. The optimum hedge ratio could then be seen as the hedge position that best achieves the hedger's specific objectives.

For the agricultural producer placing a preharvest hedge, the optimum hedge ratio takes on a slightly different meaning than is commonly found in the literature. A producer typically uses the futures or options markets to achieve a revenue goal or to reduce the impact of any unexpected changes in prices or production. By "locking in" a target revenue, the hedger is insulated from any change in prices or yields until the final sale of the cash commodity. In this sense, the optimum hedge can be seen as the ratio of futures to cash positions that most closely achieves the revenue goal established by the producer.

In an agricultural production context, the hedge ratio presented as optimum in this study is really only the optimum allocation between two marketing alternatives -- place a hedge in May or sell in the spot market at harvest. In reality, a producer has many different marketing alternatives and new information becoming available throughout the production process. The decision of how much to sell in any time period is also influenced by storage availability, cash flow needs, tax considerations, a farmer's unique utility function, and a farmers own expectations about future price movements. A true dynamic optimum hedge ratio estimator would have to account for all of these considerations.

For the farmer who needs or wants to sell a portion of the crop prior to harvest, the minimum variance hedge ratio may be considered a reasonable proxy for the true optimum hedge ratio. Once the decision to hedge prior to harvest has been made, the farmer must still address the issue of hedge ratio determination. If quantity was known precisely, a price level optimum hedge ratio might be appropriate. Since quantity can only be estimated, a different approach is needed. The next section of this paper reviews the relevant research on the price risk minimizing and the price and quantity risk minimizing hedge ratio estimators.

Price Risk Minimizing Hedge Ratios

The simplest and most frequently used approach to hedge ratio estimation in the grain markets is the equal and opposite rule -- for each bushel held in the cash market, a bushel should be sold in the futures market. The equal and opposite rule is taught in many introductory agricultural marketing courses because it is easy to understand and implement in applied hedging situations. This approach is based on the idea that as prices rise or fall in the cash market, the profits (losses) in the cash market will be exactly offset by losses (profits) in the futures market. The equal and opposite rule has some justification if the futures contract specifications exactly match the cash position and futures and cash prices move in a parallel fashion. Since the futures contract price is an estimate of supply and demand conditions for a specific location and time in the future, and the cash price reflects local supply and demand conditions at the present, there is little reason to expect these prices to move in perfect unison.

This "one to one" hedge ratio also presumes a known quantity, which is not appropriate for a preharvest hedge. At the national level, low yields often lead to high prices and high yields often result in low prices. From a risk management perspective, this negative correlation between price and yield reduces the variability of revenue, and therefore it reduces the optimum hedge position. Grant (1987) calls this the "natural hedge" effect.

Researchers have developed several alternative methods of estimating the optimum ratio of futures to cash positions and have assigned many different objective functions to the hedger. These functions range from Working's (1977) profit maximization view of hedging to the idea that hedgers are trying to eliminate all risk. The portfolio theory of hedging falls between these two extremes and attempts to find the optimum tradeoff between risk and return. When futures prices are considered unbiased, the portfolio theory suggests using the minimum variance hedge ratio estimators. The minimum variance hedge ratio estimators have now become the most popular with modern economists.

Most of this research has centered on minimizing price risk with fixed quantities (e.g., storage hedges). Although these optimum hedge ratio estimators do not specifically address the issue of quantity risk, they provide the foundation for hedge ratio estimators that can. The standard approaches to estimating the minimum variance hedge ratio rely on regression techniques. Typically, a futures price series is regressed against a cash price series. These price series consist of price levels, price changes, or percentage price changes. Determining which price series is most appropriate has created considerable debate.

Witt, Schroeder, and Hayenga (1987) addressed this issue and concluded that the objective function of the hedger should determine which type of price series was most appropriate. A preharvest hedger who is not hedging a current cash position would not be concerned with changes in the current cash price. Therefore, a price level regression, which relates the cash price at harvest to the futures price at harvest, provides the most reasonable framework for a preharvest hedge ratio estimator that minimizes pure price risk. This technique uses the ratio of the covariance of futures and cash price levels to the variance of futures price levels as an estimate of the optimum hedge ratio. This ratio is equivalent to the regression coefficient of cash price levels regressed on futures price levels during the period when the hedger would be lifting the hedge and liquidating his or her cash position. The regression equation is

(2.1) $$p_t = \alpha + \beta f_t + \epsilon$$

where:

p_t = the cash price at harvest.

f_t = the futures price at harvest.

β = the regression estimate of the hedge ratio.

The price level regression does not account for the impact of variable quantities and would only be applicable to futures hedge positions. The major drawback of using price level regressions, however, is a potential problem with autocorrelation. There have been several proposed solutions for handling the autocorrelation. The first possible solution involves switching to a price change model. The price change model substitutes price changes for price levels in the regression equation. Typically the price differencing pattern matches the frequency of the hedger's data -- usually a day, a week, or a month. Taking k^{th} order price differences (changes) of both cash and futures prices assumes a k^{th} order autocorrelation coefficient of one. Therefore, unless the order of differencing equals the order of autocorrelation with a rho coefficient near one, there is no reason to prefer price change models over price difference models, especially for anticipatory hedges. The ability to use previous errors in the typical hedging process also requires a long error lag structure, which is probably not significant in most hedging situations.

Additionally, the appropriate price change ought to be the change in prices observed over the period of time when the hedge is in place, especially for storage hedges. Otherwise, it is not clear that the price and time relationships being used to estimate the hedge ratio will conform with those being used in an actual hedging situation.

Another approach is to use Generalized Least Squares (GLS) instead of Ordinary Least Squares (OLS) to estimate the hedge ratio. Witt, Schroeder, and Hayenga (1987) evaluated the GLS approach and concluded that while it improved the statistical efficiency of the price level model, the GLS technique made only minor differences in the actual hedge ratio estimates. Moving to an unconstrained stacked multiple regression model with different intercepts and slope coefficients for each contract, while not appreciably changing the hedge ratio estimates, would allow the hedger access to the most recent errors in the model as opposed to errors that occurred a year earlier. The usefulness of incorporating such error information, however, is limited when considering hedges that will be lifted more than one or two months into the future, such as placing a hedge at planting time and holding it approximately five months until harvest.

Another possible solution for handling the autocorrelation issue is to move to a generalized optimal hedge ratio estimator, as proposed by Myers and Thompson (1989). The price level and price change models, typically estimated by Ordinary Least Squares, rely on the unconditional variance and covariance of prices, while the generalized model uses conditional variances and covariances to estimate the hedge ratio. The generalized procedure begins by specifying a model for the determination of equilibrium cash and futures prices based on information that would be known when the hedge is placed. The conditional variance/covariance matrix and, consequently the appropriate regression equation, can be estimated from the model. In its simplest form, the regression equation is

$$p_t = \alpha_0 + \beta f_t + a(L)p_{t-1} + b(L)f_{t-1} + e_t \qquad (2.2)$$

where:

p_t is the spot price.

f_t is the futures price.

a(L) and b(L) are polynomials in the lag operator L.

The generalized hedge ratio estimator does not impose any a priori price determination assumptions, but it does require specifying a model for equilibrium cash and futures prices. Past cash and futures prices are obvious choices for the model, but other variables may also be added. Myers and Thompson (1989) tested a model that included stock levels and cross commodity effects, along with past prices, and found that these variables did not appreciably change the hedge ratio estimate for corn, soybeans, and wheat.

Price and Yield Risk Minimizing Hedge Ratios

The distinguishing feature of a preharvest hedge is that the quantity available to be hedged is not known exactly. Since yield and sometimes the planted acreage are subject to weather risk, and other production risk factors, (e.g., insects, weeds, and disease), the quantity estimate, and consequently the optimum futures or options position, would be expected to vary over the course of the production and hedging period. In a preharvest hedging situation, the producer not only has price risk to contend with, but must also adjust the hedge to account for uncertain production outcomes.

The procedures outlined in the previous section move beyond the naive assumptions of the one to one hedge. They are, however, only useful if anticipated quantity is precisely known. For unknown quantities, as in a preharvest hedge, a method for accounting for quantity risk would have to be added to the model. The next models take the first steps towards accounting for quantity risk within the optimum hedge ratio framework.

Grant (1987) addresses the yield and price risk associated with preharvest futures market hedging. His model assumes that farmers maximize their one-period expected utility of income and that futures prices and income are bivariate normal variables. These assumptions separate the model into two parts -- variance minimization and expected wealth maximization. If futures prices are unbiased, the expected wealth maximizing component of the hedge ratio estimator is shown to equal zero. The variance minimizing portion of the optimum hedge ratio is all that is considered, and this yields the familiar revenue variance minimizing hedge ratio with the addition of two components to adjust for yield risk. Grant's model is specified as follows:

(2.3) $h* = -[E(q)cov(p,f)+E(p)cov(q,f)+cov(\theta_p\theta_q,f)] / var(f)$

where:

h* is the optimum hedge ratio estimate.

p is the local cash price.

f is the relevant futures price.

$\theta q = q-E(q)$.

$\theta p = p-E(p)$.

This equation can be broken down into three components -- a price risk minimizing term, a yield risk minimizing term, and an interaction term. The first term is the price risk minimizing portion of Grant's model. It is shown as:

(2.3a) $(-q)cov(p,f) / var(f)$

This is the standard price level regression hedge ratio estimate when yield or quantity is certain.

The second term is the yield risk minimizing component when prices are certain. This term is specified as:

(2.3b) $(-p)cov(q,f) / var(f)$

The size of this term depends on the correlation between yields and futures prices. This component of the hedge ratio equation adjusts the hedge ratio estimate for the relationship between price and yield. At the national level, there is a causal relationship between price and yield, and this relationship should be negative because high prices are typically associated with low yields, and low prices with high yields. Individual farm production variations, however, will not have any impact on national price levels. Therefore, a causal relationship between prices and individual farm production does not exist. The covariance between yield and futures prices, when calculated from farm level yield data, reflects the extent to which national prices have been correlated with an individual farmer's yields.

For producers in major growing regions, there could be a high correlation between their yields and national prices. The existence of localized droughts or other isolated production failures, however, could keep this relationship from being stable over time. The effects of soil type, drainage, and climatic differences will have a long term impact on the optimum farm level hedge ratio and may cause it to deviate significantly from the optimum for the county, state, or nation. The problem of stability through time will be inherent in any hedge ratio estimator that relies on farm level yield data. Therefore, optimum hedge ratio estimates calculated at the farm level will be optimum into the future only to the extent that the correlation between a farm's yields and national prices remains stable.

The third term in Grant's equation is

$$(2.3c) \qquad \operatorname{cov}(\theta_p\theta_q, f) \ / \ \operatorname{var}(f)$$

This component impacts the hedge ratio estimate when both price and yield are variable. If cash and futures prices are highly positively correlated, this term will have the same sign as the correlation between cash prices and quantity.

Grant's model assumes a single hedge placed near the end of planting time with no revisions as new information is received. A large portion of the yield variability and the corresponding changes in harvest time prices will occur in June and July, so it seems reasonable to revise hedge positions as new weather developments influence final yields and futures prices.

Incorporation of weather data and other relevant information might significantly improve the model. It has been argued that prices contain all the information needed to determine an optimum hedge ratio and this might be true for a national or state level hedge ratio estimate. With farm level hedges, however, localized conditions may not be factored into the current futures price. For this reason, the inclusion of additional data may be helpful in estimating optimum positions at later times in the growing season. Since Grant was only estimating the optimum position at planting time, the addition of weather data would probably not have had a significant impact on his results.

Grant used yield data from 1961 to 1983 at the county, regional, state, and national level to estimate the optimum hedge ratio. For Iowa corn producers, Grant's model produced an average county level hedge ratio estimate equal to a short futures position of 73% of expected production with a hedge effectiveness measure of 57%. Grant measures hedge effectiveness as the percent reduction in revenue variance achieved by adopting the optimum hedge position. Grant, however, qualified that result by asserting that the cost of hedging and the relative insensitivity of hedge effectiveness measures may make average short futures positions of 30 to 50% of expected production a better estimate of the true optimal hedge ratio for most individual farmers.

Greenhall, Tauer, and Tomek (1984) also investigated optimum preharvest futures positions for corn producers faced with both price and yield risk. Their research used yield data from four farms in western New York and three farms in central Illinois. The optimum futures positions were determined for five different hedger objective functions. These functions include mean-variance, mean-semivariance, mean-target deviation, logarithmic utility, and variance minimization.

Mean variance analysis is commonly employed in hedge ratio estimation because it is considered consistent with the expected utility theorem if returns are normally distributed. Since the distribution of returns from corn production may be non-normal, Greenhall, Tauer, and Tomek also considered a mean-semivariance approach. The mean-target deviation objective function accounts for producers who are trying to achieve some specific level of revenue (e.g., cost of production). The logarithmic utility function allows for decreasing risk aversion as returns increase. This is in direct contrast to more common utility functions that assume risk aversion increases as returns increase. The final objective function, variance minimization, is a subset of the mean variance analysis. If futures prices are unbiased, the mean variance analysis produces the same optimum hedge position as variance minimization.

Greenhall, Tauer and Tomek's research used the average yield of the period under study as each years estimate of expected yield. Using average yields assumes that hedgers have access to data that would not have been available at the time the hedge was placed and makes the mean yield estimation error equal to zero. Since the hedge ratio is expressed as a percent of expected yield and yield estimation error is an important determinant of the optimum hedge position, the use of average yield as an estimate of anticipated yield may influence the results. Any procedure used to estimate expected yields, however, may influence the results of a hedge ratio estimation model.

Greenhall, Tauer, and Tomek calculated the optimal hedge positions for twenty-four different decision periods and six different risk aversion coefficients. This wide array of assumptions makes it difficult to summarize the results. Greenhall, Tauer, and Tomek do not provide any simple rules of thumb from their analysis of this small sample of farms, but do say that planting time hedges probably should not exceed twenty percent of expected production for central Illinois corn producers. They also conclude that as harvest approaches and yields become more certain, the optimum futures position will probably increase. Without revised estimates of the distribution of expected yields, however, it is difficult to attribute this change in the optimum position to changes in yield risk.

Karp (1987) considered the preharvest hedge ratio estimation procedure in a continuous time framework. Karp's model emphasizes dynamics and uncertain production outcomes -- two important factors in any preharvest optimal hedge ratio estimator. A dynamic model is one that anticipates changes in the hedge ratio as new information becomes available, as opposed to a myopic model that assumes the hedge ratio will not be revised once the hedge has been placed. Karp's model allows farmers to revise their hedge position over the growing season as weather or other factors change yield and price expectations.

Karp's model is based on a Constant Absolute Risk Aversion (CARA) utility function. Since the CARA parameter is unknown, a range of different parameters is used. Each parameter yields a different profit distribution, and the producer can then choose the appropriate utility maximizing hedge based on these profit distributions. This allows hedgers to see the outcomes from different levels of risk aversion. If futures prices are unbiased, however, the optimum hedge position will be the same for all levels of risk aversion. Karp suggests that if prices are determined to be unbiased, simpler methods of calculating the optimum hedge ratio could be used.

The research on optimum futures positions provides the framework for preharvest hedging in the futures market, but it does not address preharvest hedging with options. The unique characteristics of options, which make them intuitively appealing as preharvest hedging tools, also make determining the optimum preharvest option position especially difficult. The next chapter outlines the data employed to determine farm level optimum futures and options positions, and Chapter 4 explains the methods utilized to derive the optimum positions.

CHAPTER 3. DATA

Prices

Observed prices

For this study, the closing prices on the Chicago Board of Trade December corn futures contract were collected for each Thursday from 1974 through 1989. The options premiums for the at-the-money strike price were also collected for each Thursday from the start of options trading in 1985 through 1989. At-the-money options premiums for 1980 through 1984 were estimated using the Black-Scholes equation. Cash prices used in the analysis were the midpoint of the closing range on Thursday for North Central Iowa elevator bids as compiled by the Federal-State Grain Market News Department in Des Moines, Iowa. An average of the premiums and prices for the month of May was used to measure the prices and premiums trading at planting time. An average of the prices and premiums for the month of October and the first two weeks in November were used to measure prices available at harvest. In Iowa, most of the corn is planted and harvested within those time periods.

Expected prices

The harvest basis was calculated as the average of the futures prices minus the cash prices for each Thursday in the harvest period. The anticipated harvest basis was defined as the average of three previous years actual harvest basis. The anticipated cash price was defined as the futures price at planting less the anticipated basis. The anticipated[1] harvest futures price was the planting period December futures price (i.e. futures prices were assumed to be unbiased).

Yields

Observed yields

Individual farm yield data was compiled by National Crop Insurance Services. This data consisted of farm specific yields for farms in Iowa from 1980 to 1989. The farm locations represented nearly all counties in Iowa. Only those farms with a complete ten year production history were included in this study and a random sample of 250 (approximately 10%) farms was used for the analysis. The average yields from the National Crop Insurance Services farm population were highly correlated with state and county level average yields, and appear to provide a representative sample of farm level yield variability for Iowa. The average yields, however, were higher than the USDA's yield estimates for the corresponding individual counties and for Iowa. Average

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[1] Since the process used to estimate harvest yields and prices might vary among farmers, the terms anticipated and expected are used interchangeably to refer to the farmer's estimate of the conditions prevailing at harvest.

yield data was also collected for each of the ninety-nine counties in Iowa from 1965 to 1989. This data came from the Iowa Agricultural Statistics publications and was compiled by the Iowa Department of Agriculture and Land Stewardship and by the U.S. Department of Agriculture, National Agricultural Statistics Service.

Expected yields

Yield expectations play a crucial role in determining the optimum preharvest hedge ratio. The best method for determining anticipated yields would be to interview farmers when the hedge would have been placed and record their expectations. Unfortunately, this type of data is not available. Another possible procedure would involve using a moving average of lagged yields, but the available data set was too short. Instead, a linear projection based on past county yields was used as a starting point for estimating the yield expectations of individual farmers. The differences between each farm's actual yields and the actual county yields were calculated and this farm-county yield differential was used to adjust the projected county yields for differences in each farm's likely production capability. Each farmer's 1981 yield expectation was estimated by subtracting the 1980 farm-county differential from the projected 1981 county yield. The anticipated farm yield for 1982 was the projected county yield for 1982 minus the average of the farm-county yield differential for 1980 and 1981. This process of adding an additional lagged farm-county yield differential each year was repeated until a maximum of four lagged farm-county differentials were used in the calculation of anticipated farm yields for 1984 to 1989. This process provided unique estimates for each farm and, most importantly, allowed yields to be estimated without using data unavailable to the farmer at the time when the hedge would have been placed. The equations for calculating anticipated yields for the individual farms are shown as:

(3.1) $E(YLD_{F,1981}) = E(YLD_{C,1981}) - C\text{-}F_{1980}$

(3.2) $E(YLD_{F,1982}) = E(YLD_{C,1982}) - C\text{-}F_{AVG(1980..1981)}$

(3.3) $E(YLD_{F,1983}) = E(YLD_{C,1983}) - C\text{-}F_{AVG(1980..1982)}$

(3.4) $E(YLD_{F,1984}) = E(YLD_{C,1984}) - C\text{-}F_{AVG(1980..1983)}$

(3.5) $E(YLD_{F,1985}) = E(YLD_{C,1985}) - C\text{-}F_{AVG(1981..1984)}$

(3.6) $E(YLD_{F,1986}) = E(YLD_{C,1986}) - C\text{-}F_{AVG(1982..1985)}$

(3.7) $E(YLD_{F,1987}) = E(YLD_{C,1987}) - C\text{-}F_{AVG(1983..1986)}$

(3.8) $E(YLD_{F,1988}) = E(YLD_{C,1988}) - C\text{-}F_{AVG(1984..1987)}$

(3.9) $E(YLD_{F,1989}) = E(YLD_{C,1989}) - C\text{-}F_{AVG(1985..1988)}$

where:

$C\text{-}F_t$ = County yield_t - farm yield_t

$YLD_{F,i}$ = individual farm yield, year i

$YLD_{C,i}$ = county yield, year i

Yield expectations at the county, state and national level were calculated by simple linear regressions forecast one period into the future. For the state and national level hedges placed in August, the USDA's August 1st yield estimates were used as yield expectations. Since farmers would have the same information available to them as the USDA estimators, the USDA's estimates should represent a reasonable approximation of the farmer's expectations on August 1st.

CHAPTER 4. METHODS

Measuring Hedge Performance

A producer has a variety of potential methods for determining his or her optimum hedge ratio. Each of the procedures outlined has both advantages and disadvantages. In general, simplicity and ease of calculation must be traded for accuracy and statistical correctness. Although simplicity and statistical correctness are important characteristics in a hedge ratio estimator, they are not the most important. The feature of greatest importance for practical applications is performance. Research on hedge ratio estimates often report coefficients of determination or other measures of statistical effectiveness, but seldom do they measure hedge ratio performance in terms that are relevant to the typical agricultural producer.

For the agricultural producer, the measure of performance needs to reflect the hedger's goal. As mentioned earlier, the preharvest hedger is assumed to be using the futures or options to lock in a revenue goal. Since there is no current cash position, preharvest hedgers are not trying to offset price changes in the cash market by holding an opposite position in the futures market. Instead they are interested in achieving their target revenue. In the case of futures this is an absolute revenue goal. For an options hedge, the revenue of interest is the minimum revenue offered by the options market. With futures, any deviations from expected revenue may be considered adverse. With options, only deviations that cause actual revenue to be less than minimum revenue are considered adverse. Since deviations from expected revenue play an important role in determining the optimum hedge position, it is necessary to define how expected and actual revenues are calculated in the following analysis.

Actual and Expected Futures Revenue

To simplify the estimation of expected revenue for futures hedging, several assumptions are made. The current futures price is assumed to be an unbiased estimator of the futures price that will prevail when the futures contract expires. The cash price at harvest can also be estimated from the current futures price. The expected cash price at harvest is simply the current futures price less the basis that is expected to prevail at harvest.

Following these assumptions, the actual and expected revenues for a futures market hedge are shown by:

(4.1) $$REV = pq + (f_{t-1} - f_t)*h*q$$

(4.2) $$E(REV) = E(p)E(q) + cov(p,q) + (f_{t-1} - E(f_t))*h*E(q)$$

If f_{t-1} is an unbiased estimator of f_t, then

(4.3) $$E(f_t) = f_{t-1}\ ,\ E((f_{t-1} - E(f_t))*h*q) = 0,\text{ and}$$

(4.4) $E(REV) = E(p)E(q) + cov(p,q)$

where:

h is the optimum hedge ratio estimate

f_{t-1} is the current futures price.

f_t is the harvest period futures price.

p is the cash price at harvest.

E(basis) is the farmer's estimate of harvest basis.

q is the farmer's actual production.

The relationship between prices and the quantity produced by an individual farm (i.e., cov(p,q)) is not causal. Historically, the covariance between prices and yields on a single farm might be significantly different than zero, but the production from a single farm in any given year will have no impact on prices due to the atomistic nature of corn production. Therefore, the expected covariance between price and yield for an individual farmer is assumed to equal zero.

Using information available in the futures market and assuming cov(p,q) = 0, the cash price at harvest and the expected revenue from a futures hedge are shown by:

(4.4) $E(p) = [f_{t-1} - E(basis)]$ and

(4.5) $E(REV) = [f_{t-1} - E(basis)] * E(q)$

Actual and Minimum Options Revenue

When options are considered, the target revenue is really a minimum revenue. If options premiums are considered given and commission and interest costs are ignored, the actual revenue for an options hedge is shown by:

$$(4.6) \qquad REV = pq + (Prem_t - Prem_{t-1})*h*q$$

where:

$Prem_{t-1}$ is the current options premium.

$Prem_t$ is the harvest period options premium.

p is the cash price at harvest.

E(basis) is the farmer's estimate of harvest basis.

q is the farmer's actual production.

With an options position, the farmer's minimum revenue would occur if $Prem_t$ was equal to zero. Assuming the worst case scenario of $Prem_t = 0$, the minimum revenue is shown by:

$$(4.7) \qquad MIN\ REV = E(p)E(q) + cov(p,q) - (Prem_{t-1}*h*q)$$

Since only at-the-money options were considered, (i.e., the strike price closest to the current underlying futures price), the minimum revenue for an options hedge is the same as the expected revenue from a futures hedge less the price of the initial premium. Again, the covariance between prices and the production on an individual farm is assumed equal to zero. The minimum revenue for an options hedge is shown as:

$$(4.8) \qquad \text{MIN REV} = [f_{t-1} - Prem_{t-1} - E(basis)] * E(q)$$

Since only at-the-money strike prices were considered, the minimum revenue can also be expressed as:

$$(4.9) \qquad \text{MIN REV} = [\text{Strike price} - Prem_{t-1} - E(basis)] * E(q)$$

Deviations From Expected and Minimum Revenue

The risk a hedger is faced with is that actual revenue will not equal expected revenue (or that actual revenue will be less than the minimum revenue in the case of options hedges). The deviations from expected revenue for futures hedges are defined as expected revenue minus actual revenue and these deviations can be used as one measure of risk for the hedger. Since each hedger will weight these deviations according to their own utility function, the deviations are categorized to allow consideration of various hedger objective functions. The deviations are categorized as:

positive: $(E(REV) < REV)$.

negative: $(E(REV) > REV)$.

total: $(E(REV) \neq REV)$.

For options hedges, the deviations are calculated from the minimum revenue. These deviations are categorized as:

positive: (MIN REV) < REV).

negative: (MIN REV) > REV).

total: (MIN REV) ≠ REV).

Determining the Optimum Futures and Options Position

Determining the appropriate objective function for an individual hedger has been a major obstacle in evaluating optimum hedge positions. The research in this area has produced a variety of possible objective functions that range from profit maximization (Working 1977) to various alternative forms of variance minimization. Greenhall, Tauer, and Tomek (1984) applied several of these differing objective functions to evaluate the optimum futures positions for the wide variety of hedging goals that individual farmers might have. The specific objective functions used by Greenhall, Tauer, and Tomek were discussed in the review of literature in Chapter 2.

Several different hedger objective functions are also developed in this paper to account for the range of reasonable goals a hedger might have. The hedger objective functions in this paper are based on the categories of deviations from minimum and expected revenue that were outlined in the previous section. From most hedgers' perspectives, positive deviations are probably perceived as revenue windfalls, while the negative deviations represent undesirable outcomes. Based on these deviations and how they would reasonably be evaluated by hedgers, three optimum futures and two optimum options positions are developed. These optimum positions are based on various measures of the deviations from expected revenue and various possible objective functions for the hedger. The optimum futures and options positions are specified as:

Futures Obj. #1) $\text{MIN } \Sigma_{1981\text{-}1989} [E(REV) - REV]^2$

Futures Obj. #2) $\text{MIN } \Sigma_{1981\text{-}1989} [E(REV) - REV]^2 \quad \forall\ E(REV) > REV$

Futures Obj. #3) $\text{MIN } \Sigma_{1981\text{-}1989} [E(REV) - REV]/E(REV)$

Options Obj. #1) $\text{MIN } \Sigma_{1981\text{-}1989} [(\text{MIN REV}) - REV]^2$

$\forall\ (\text{MIN REV}) > REV$

Options Obj. #2) $\text{MIN } \Sigma_{1981\text{-}1989} [(\text{MIN REV}) - REV]/\text{MIN REV})$

$\forall\ E(REV) > REV$

Futures objective #1 minimizes the sum of all squared deviations from expected revenue. This optimum position is similar to the regression approach used to calculate optimum hedge ratios for a mean-target deviation model. This approach is not valid for options hedges because the purpose of options is to establish a price or revenue floor. With an options hedge, the goal is to only eliminate the negative outcomes while leaving the upside potential. For this reason, the objective functions specified for options hedges only consider the negative deviations from minimum revenue.

Options objective function #1 minimizes the sum of negative deviations from minimum revenue. This objective function was also imposed on the futures hedger (futures objective #2) to determine how effective a futures position can be in establishing a revenue floor.

The deviations from expected and minimum revenue are also minimized in percentage terms to provide a more understandable measure of both the magnitude of deviations and the sensitivity of the hedge ratio estimates. Additionally, expressing the deviations in percentage terms standardizes the weighting of the results from individual years so a scaling difference in the price levels would not influence the results. Futures objective #3 minimizes positive and negative percentage deviations from expected revenue, while options objective #2 minimizes only the negative percentage deviations from minimum revenue.

A numerical simulation procedure was used to determine the returns and variability of returns for 250 farms with varying futures or options positions placed at planting time and liquidated at harvest. The yields, expected yields, and relevant prices and premiums are used to calculate actual, expected, and minimum revenues based on the equations outlined in Chapter 4. The simulations evaluated hedge ratios from a long position of 100% of expected production to a short position of 300% of expected production in 1% increments. The deviations from expected revenue are then divided into positive and negative categories, expressed as percent of expected revenue or squared (depending on the particular objective function) and summed for each hedge ratio for the years 1981 to 1989. The hedge ratio that best satisfies the specific objective function being analyzed is selected as optimal.

CHAPTER 5. RESULTS

This chapter provides a summary and comparison of the results for the different types of yield data and hedger objective functions. The revenue deviations were calculated for planting time hedge ratios ranging from a long position of 100% of expected production to a short position equal to 300% of expected production. The optimum futures and options positions were determined from several different types of yield data. The different types of yield data include:

250 individual farms

50 individual farms in Boone county

50 individual farms in Webster county

7 Iowa county USDA averages (including Boone and Webster)

Iowa USDA average

U.S. USDA average

The Iowa and U.S. optimum hedge ratios were also determined for hedges placed in August, when the first USDA yield estimates are made, and lifted at harvest.

Individual Farm Optimum Hedge Positions

To illustrate the methods used, the expected and actual revenues for an individual farm were calculated for hedge ratios ranging from a short futures position of 200% of expected production to long futures position of 100% of expected production. Figure 1 provides a chart of positive, negative and total deviations from expected revenue, squared and summed from 1981 to 1989, for this sample farm.

All deviations from expected revenue are minimized when the futures hedge ratio is equal to a short position of 52% of expected production. Negative deviations from expected revenue are minimized when the futures hedge ratio is set equal to 67% of expected production.

Average revenue was maximized at the largest short position considered. The returns to holding a short futures position from planting until harvest were positive, on average, from 1981 to 1989. Therefore, the larger the short futures position, the higher average revenue was. If a hedger's goal was revenue maximization, holding the largest short futures position possible would have been optimum for the 1981 to 1989 period.

Figure 2 shows the outcomes from options hedges for the same farm. The characteristic of unlimited upside potential for put options positions makes it undesirable to minimize all deviations from minimum revenue; therefore, the optimum options hedge ratio will occur when the negative deviations are minimized (i.e., where the price floor is most effective). For this particular farm, the sum of the negative deviations is minimized at a hedge ratio equal to purchasing puts at 255%

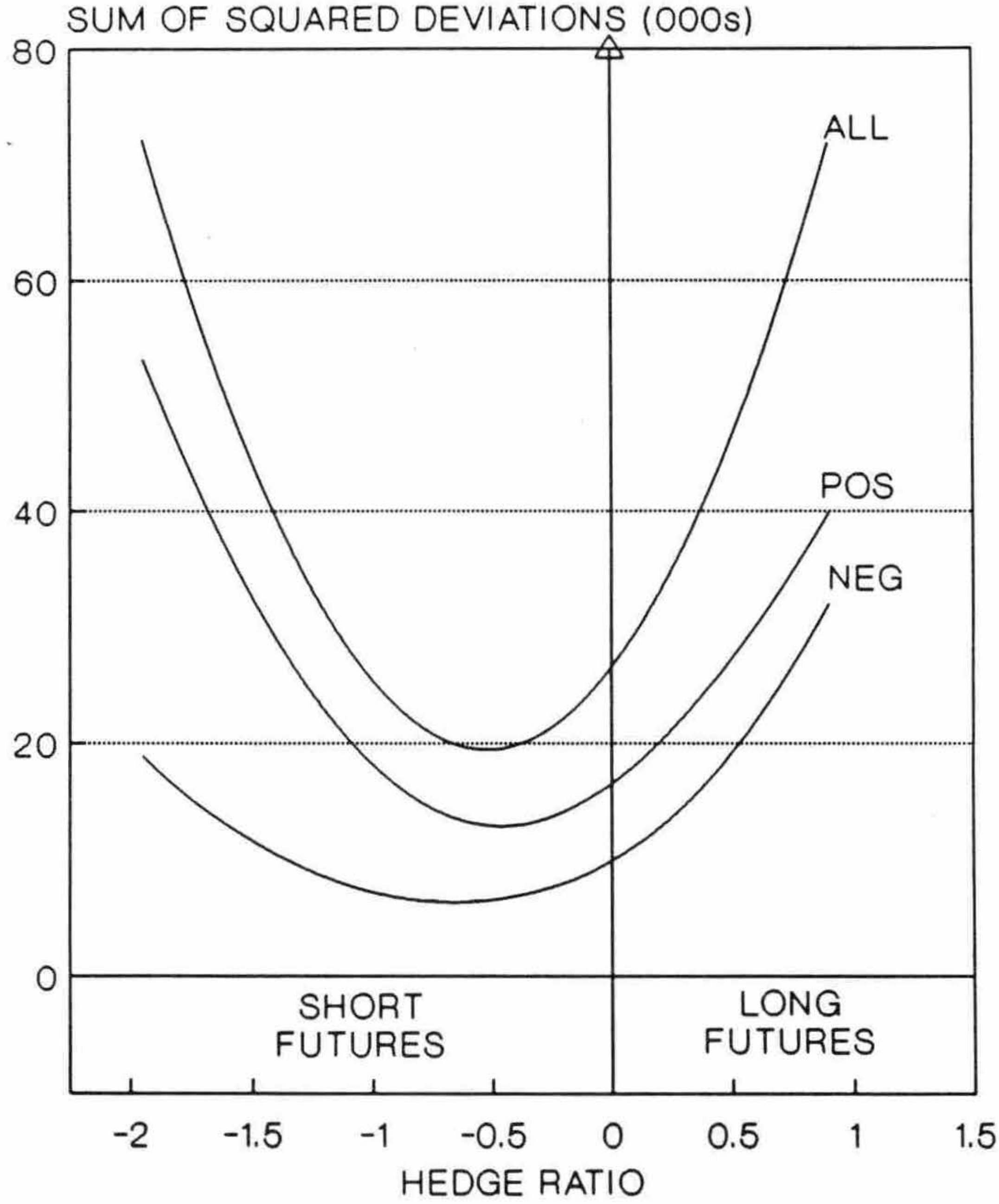

Figure 1. Futures hedge results for a randomly selected farm, 1981 - 1989, futures objective #1

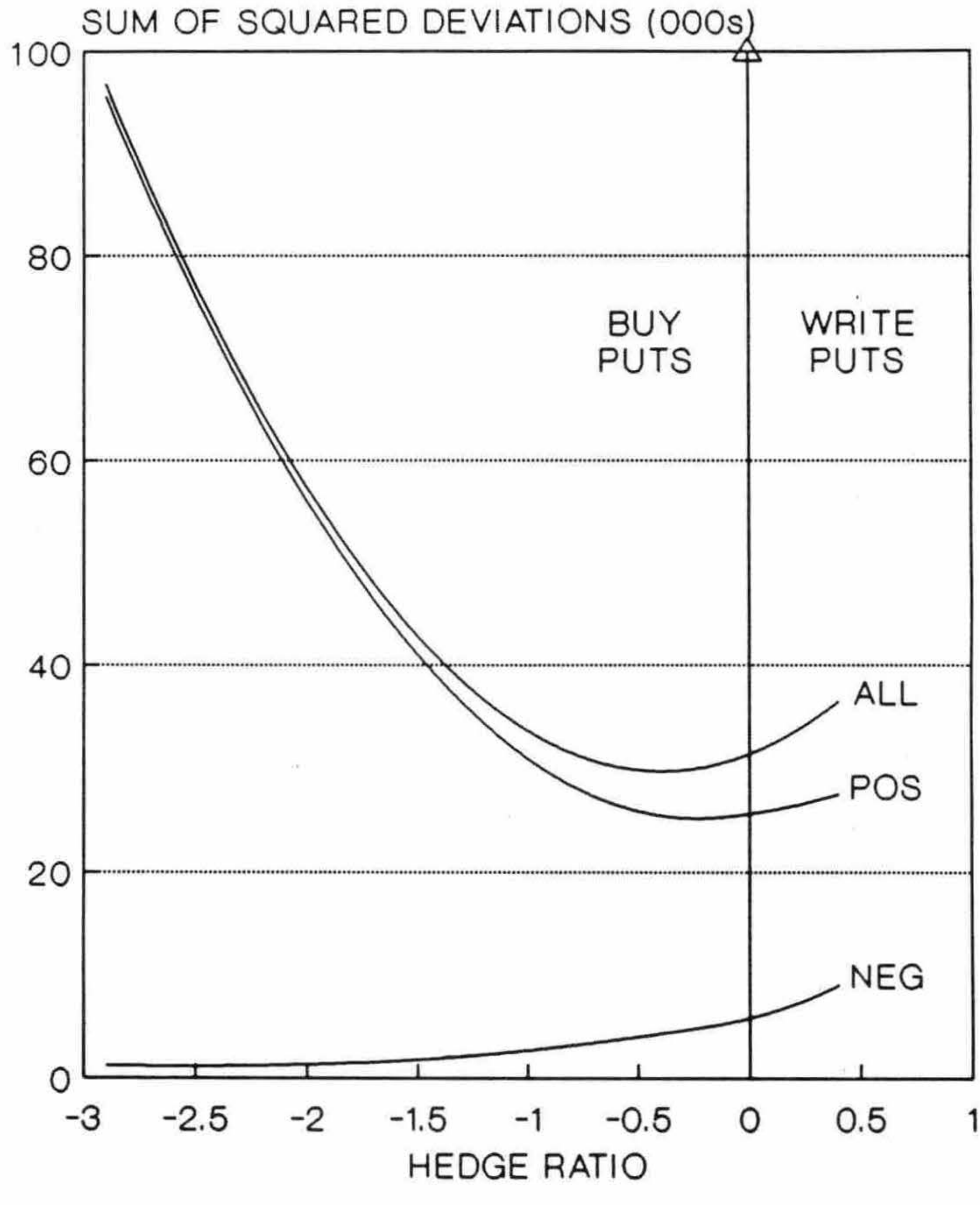

Figure 2. Options hedge results for a randomly selected farm, 1981 - 1989, options objective #1

of expected production. Very little additional risk reduction results as the hedge ratio increases beyond 150%. The negative deviations remain very close to zero when the hedge ratio ranges from 150% to 400% of expected production.

Similar to the futures hedging example, revenue is maximized at the largest long put option position. This can be attributed to the fact that, on average, the December corn futures declined by approximately $.07 per bushel from planting to harvest during 1981 to 1989.

The summary statistics from simulated futures and options hedges for the 250 individual farms are in Table 1. Figures A.1 through A.5 graph the distribution of optimum hedge ratios for the 250 individual farms for each of the objective functions. The optimum hedge ratios are distributed across the entire range of futures and options positions that were considered. The distributions reach a maximum near the average optimum hedge ratio for each objective function, but, considering the wide range of positions evaluated, the distributions are quite flat. These results suggest that using simple rules of thumb to approximate the true optimum position may lead to very non-optimum results for many preharvest hedgers.

Averaging across all 250 farms studied, the optimum planting time futures hedges (futures objective #1) which could have reduced all deviations from expected revenue by an

Table 1. Summary statistics on 250 individual farm hedge ratio evaluations

Futures objective #1) Minimize sum of all squared deviations from expected revenue

	AVERAGE	RANGE
HEDGE RATIO:[a]	-.39	+.90 TO -1.85
HEDGE EFFECTIVENESS:[b]	27%	0 TO 87
CHANGE IN REVENUE:	3%	-6 TO 17%

Futures objective #2) Minimize sum of all negative squared deviations from expected revenue

	AVERAGE	RANGE
HEDGE RATIO:[a]	-.49	+.90 TO -1.90
HEDGE EFFECTIVENESS:[b]	36%	0 TO 100
CHANGE IN REVENUE:	4%	-6 TO +17%

Futures objective #3) Minimize sum of all percentage deviations from expected revenue

	AVERAGE	RANGE
HEDGE RATIO:[a]	-.41	+.90 TO -1.62
HEDGE EFFECTIVENESS:[b]	16%	0 TO 66%
CHANGE IN REVENUE:	3%	-7 TO +15%

Table 1. Continued

Options objective #1) Minimize sum of all negative squared deviations from minimum revenue

	AVERAGE	RANGE
HEDGE RATIO:[a]	-1.21	+.32 TO -2.90
HEDGE EFFECTIVENESS:[b]	62%	0 TO 100%
CHANGE IN REVENUE:	9%	-3 TO +29%

Options objective #2) Minimize sum of all negative percentage deviations from minimum revenue

	AVERAGE	RANGE
HEDGE RATIO:[a]	-1.51	0 TO 2.90
HEDGE EFFECTIVENESS:[b]	56%	0 TO 100%
CHANGE IN REVENUE:	12%	1 TO 30%

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[a] Short futures positions and long put options positions are indicated by a negative sign preceding the hedge ratio, while long futures positions and short put options positions (puts written) are indicated by positive signs. The hedge ratio is expressed as the percent of expected quantity held in the futures or options markets.

[b] Hedge effectiveness, R^2, is defined as the percentage reduction in the sum of the appropriate deviations resulting from hedging at the specified optimum level.

average of 27% was a short futures position of 39% of expected production. The alternative objective of hedging to reduce only the negative deviations from expected revenue (futures objective #2), reduced negative deviations by 36%. The average optimum short futures position for this objective function was 49% of expected production. Hedges placed to minimize percentage deviations from expected revenue (futures objective #3) had an average optimum short futures position of 41% of expected production and an average effectiveness of 16%. For some farmers, most of the revenue deviations could have been eliminated and all of the negative deviations could have been prevented. However, there were some farms where futures hedging would not have caused any reduction in the deviations from expected revenue for any of the three futures objective functions. These farms are characterized by unusual yield patterns that had extremely low correlation with the futures market.

During the 1980s, taking a short futures position at planting time generated positive revenue. The average increase in revenue created by futures hedging was 3% for hedging at the level that minimized all deviations from expected revenue, 4% for hedging at the level that minimized negative deviations from expected revenue, and 3% for hedging to minimize percentage deviations from expected revenue. Since there was an average positive return to holding a short futures positions from planting to harvest, average revenue increased as the size of the futures position increased. Revenue would have been maximized by holding the largest possible futures position.

When the objective was establishing a revenue floor (options objective #1), the average optimum long put option position for the 250 farms was 121% of expected production. That position produced an average reduction in negative squared deviations of 62%. Options hedges placed to minimize negative percentage deviations from expected revenue (options objective #2) resulted in an average optimum long put position of 151% of expected production with an average effectiveness measure of 56%. Some farmers could have eliminated all deviations from expected revenue, while hedging with options would not have eliminated any of the deviations from expected revenue for others. Farms with unusual yield patterns had the lowest hedging effectiveness while farms that followed the typical yield patterns had the highest measures of hedge effectiveness.

The optimum planting time options position would have increased revenues, on average, by 9% and 12% for options objectives #1 and #2, respectively. Since interest and commission charges were not calculated, the true increase in average revenue would have been somewhat smaller. As with futures, there was an average gain from holding a long put option position and revenues increased as the size of the options position increased.

Sensitivity tests were conducted to evaluate the impact of changes in the hedge ratio on hedge effectiveness. This was done by measuring hedge effectiveness at hedge ratios on both sides of the optimum position. The hedge ratio was evaluated at the optimum position ± .10 (e.g., .40 and .60 if the optimum position was .50) for a random sample of 50 individual farms (20% of the farms analyzed) for futures objective #1 and options objective #1. Hedge effectiveness changed, on average, by 1% for the futures hedges and by .4% for the options hedges. The maximum change in effectiveness was 4% and 2% for the futures and options, respectively.

The direction the hedge ratio was moved from the optimum did not make a significant difference for futures hedges. For the options, changes that increased the hedge position had a slightly smaller impact on hedge effectiveness than changes that decreased the overall size of the hedge position. The non-normal return distributions for options hedges are probably responsible for this effect. The revenue variability for individual farms is not very sensitive to moderate changes from the optimum hedge level.

Hedge Ratio Variability Across Farms

The estimates of the optimum futures and options positions vary substantially across farms. The same price series and assumptions were used for all the farms, therefore, any differences in the hedge ratio estimates must be attributed to differences in yield behavior relative to predicted yields. Yield variability is one source of risk in preharvest hedging decisions, and the variability of yields would be likely to influence the hedge ratio estimate. Equation 2.3 shows the effect of the covariance of yields and futures prices on the optimum hedge, but it does not illustrate the impact of yield variability directly. To show the effect of yield variability on the optimum hedge position, the standard deviations of farm yields are plotted against the hedge ratio estimates produced under futures objective #1.

A scatterplot of this data is presented in Figure 3. The figure shows that there is some relationship between yield variability and the estimated optimum futures position. As yields become more variable, the hedge ratio estimate generally moves away from the price risk minimizing hedge ratio estimate. The correlation coefficient between the estimated optimum hedge position and the standard deviations of yields is 0.396. There are some farms, however, where the relationship between yield variability and optimum position does not hold. To determine some of the additional factors

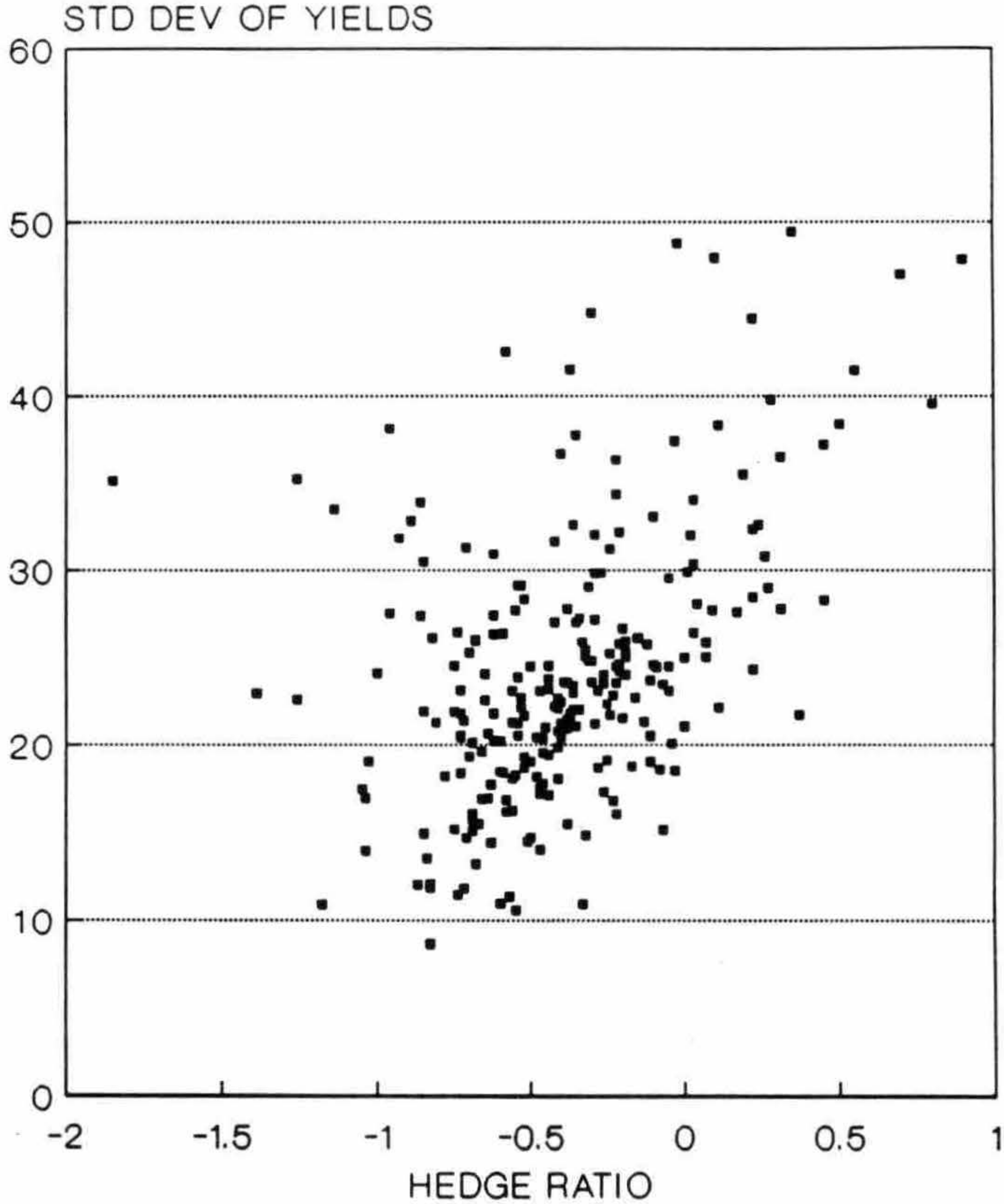

Figure 3. Estimated hedge ratio versus standard deviation of yields, futures objective #1

influencing the optimum hedge position, the effects of several other variables were also considered.

The procedure used to estimate expected yields could also have an impact on the hedge ratio estimates, especially if it were biased. Figure 4 is a plot of the optimum hedge ratio estimates versus the average yield estimation error. The correlation coefficient between average estimation error and the optimum hedge ratio estimate was -0.28. The standard deviation of yield estimation errors and the range of yield estimation errors were also plotted against the hedge ratio estimates. These variables had correlation coefficients with the hedge ratio estimate of 0.475 and 0.442, respectively.

Additional insight into the hedge ratio estimates can be gained from Figure 5. A correlation coefficient was calculated for each farm by correlating the change in the futures price over the hedge period and the difference between expected and actual yields for each year from 1981 to 1989. A negative coefficient occurs if the farm experienced relatively low yields (low in relation to expectations) and prices were high; and if yields were relatively high, and prices were low. This coefficient is one way of measuring how much revenue variability is eliminated by the "natural hedge" effect.[1] Figure 5 graphs the relationship between the hedge ratio

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[1] This is similar to the procedure used by Grant(1987).

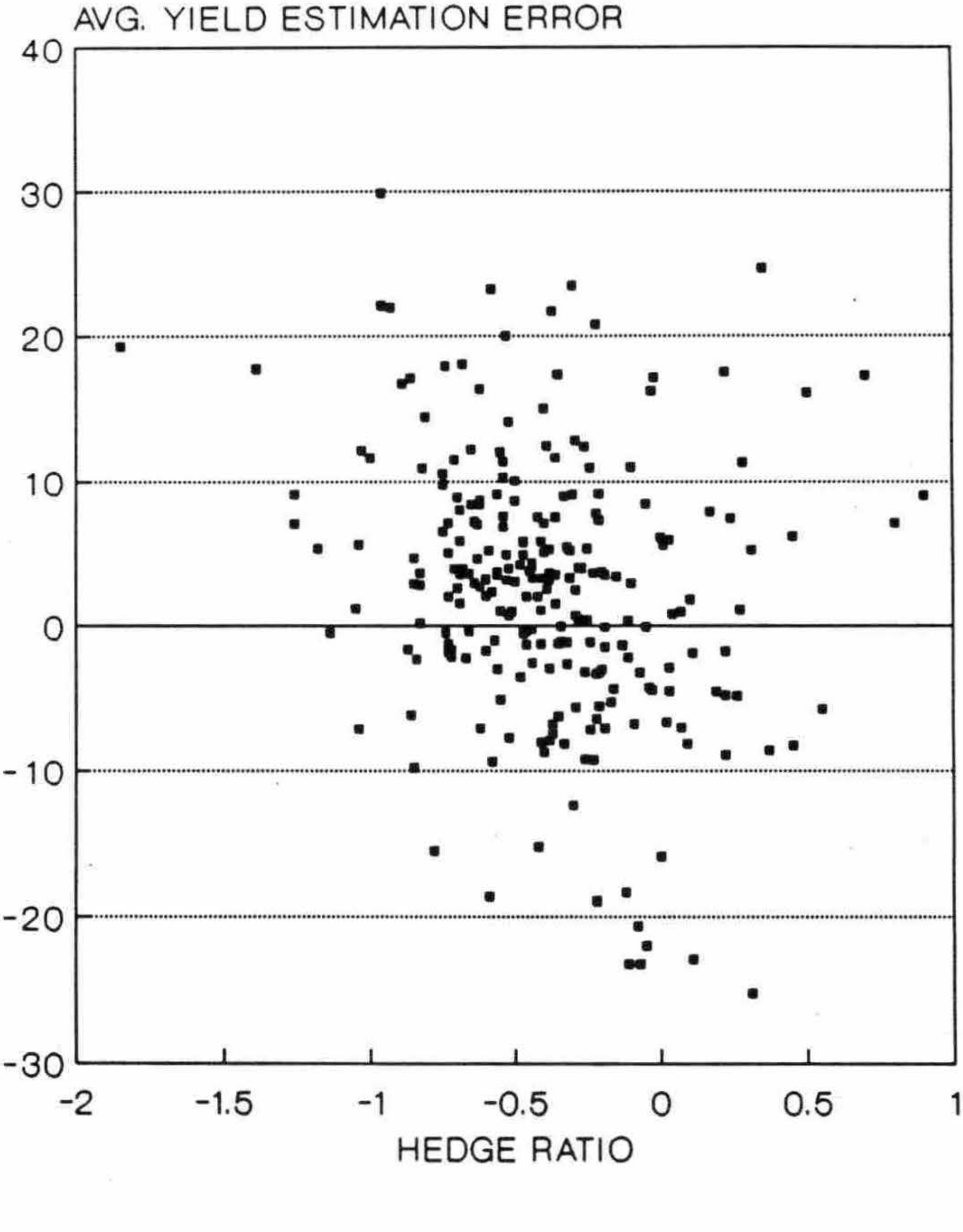

Figure 4. Estimated hedge ratio versus average yield estimation error, futures objective #1

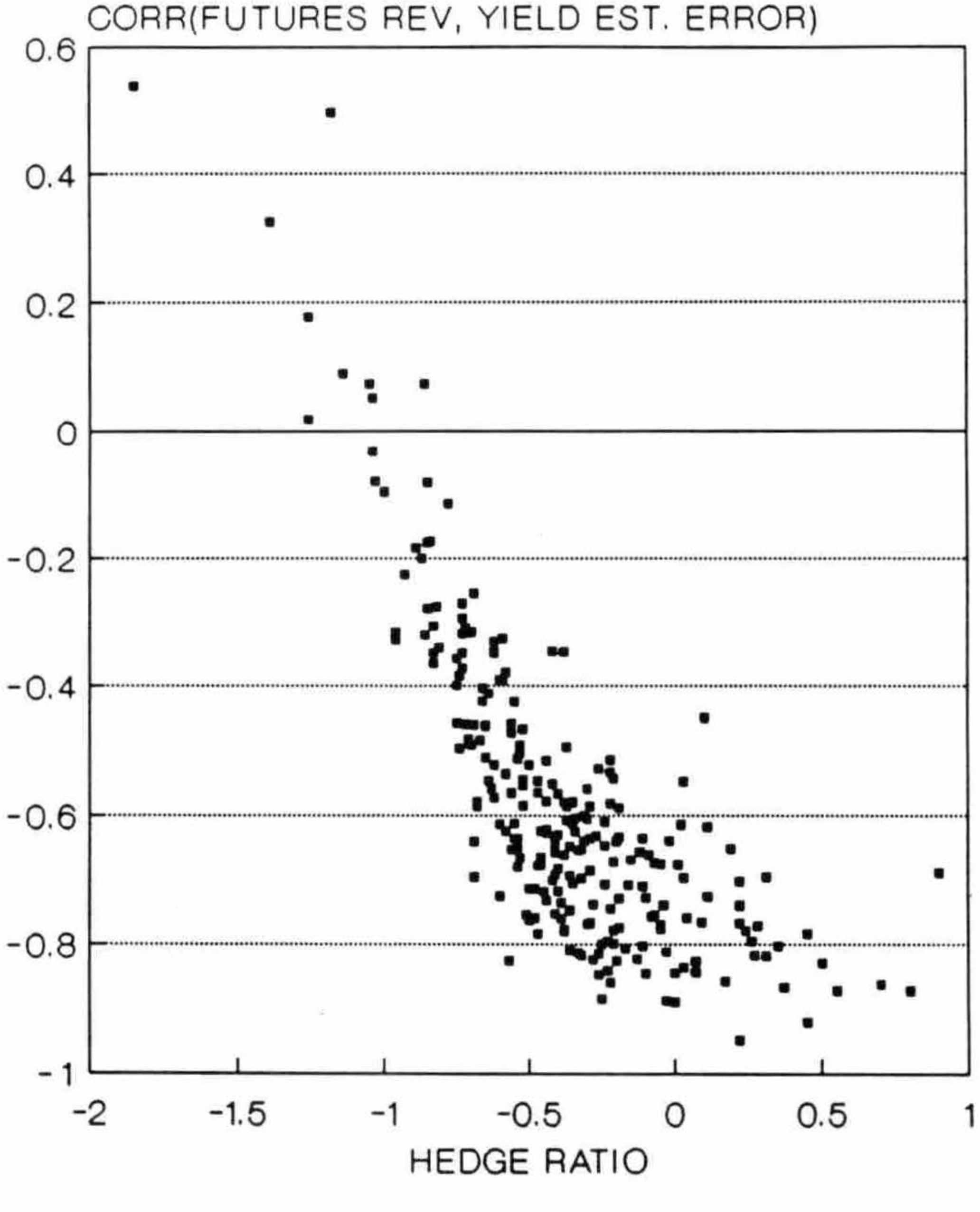

Figure 5. Estimated hedge ratio versus correlation (futures revenue, yield estimation error)

estimate and the correlation coefficient of the change in the futures price and the yield estimation errors.

The relationship between these two variables appears to be quite strong. The estimated optimum hedge ratio and the correlation coefficient between futures revenue and yield estimation error have a correlation coefficient of -0.81 for the 250 farms analyzed. Most of the correlation coefficients between futures revenue and yield estimation error were between -.40 and -.60, and only 3% of the farms had positive correlation coefficients. As the correlation coefficient between futures revenue and yield estimation error becomes less negative, revenue becomes more variable and a larger futures position is needed to offset the increased variability. Farms with large negative correlations have an almost perfect "natural hedge" and require only a small futures position to minimize revenue risk. Those farms with positive correlation coefficients need the largest futures positions because futures prices and their own yields tend move in the same direction, thus increasing the variability of revenue.

Individual Farm Versus County Hedge Ratios

County yield data is often used to estimate the optimum hedge position for individual farms within a county because county yield data is readily available. The process of averaging across farms to calculate a county average yield reduces the yield variability relative to that experienced on individual farms in that county. The reduced variability found in county yield data may cause the optimum hedge ratio estimates calculated from county data to be poor estimates of both the hedge ratio for and the risks faced by individual farms in the county. To test the validity of using county data as a proxy for individual farm yields, county level hedge ratios were calculated for seven counties in Iowa (two in the North Central district and one in each of the other five price reporting districts). The summary statistics from these counties are at the end of this chapter in Table 2. The optimum positions for fifty farms from Boone and fifty farms from Webster county were also determined to compare with the hedge ratios calculated from the aggregate county yield data. The optimum hedge ratios for Boone and Webster county, along with the summary hedge ratios for the fifty farms from each county are presented in Table 3.

Optimum hedge ratios determined with county data were reasonably close to the average hedge ratio calculated from farms within the county. The differences between the mean calculated with USDA data and the mean calculated from the individual farm data could be sampling error because fifty farms represent approximately 2% of the total farms within these counties. On an individual basis, however, many of the farms within a county had quite different optimum futures and options positions than the county average. This suggests that while county level hedge ratios may provide insight into the optimum position for the "typical" producer within a county, the optimum position for many producers could be significantly different than the county average. Differences in soil type, drainage, production practices, and weather patterns within a county may cause the yield patterns for individual farms to vary substantially from the county average yield patterns and their correlation with futures prices.

Planting Time Versus August 1 Hedge Placement

As the price and yield risk distributions narrow over the course of the growing season as more knowledge becomes available regarding the supply and demand conditions at harvest, the optimum futures or options position would also be expected to change. To evaluate how the optimum hedge position changes over time, planting time and August 1 estimates of the optimum futures and options positions were made using state and national average yield data.
Ideally, hedges placed at several different times within the growing season would have been evaluated for the individual farms. The USDA's yield estimates made it possible to evaluate expected yields and hedges for Iowa and U.S. on August 1, but no such data is available at the farm level.

The optimum futures and options positions for Iowa and the U.S. on August 1 were determined with December futures prices on or near August 1 and the yield estimates released by the USDA in their August 1 crop reports. The results from this analysis are presented at the end of this chapter in Table 4. Pure price risk minimizing hedge ratios were determined for these same time periods and are also presented in Table 4.

When price risk is considered by itself, hedge ratio estimates are relatively stable from May to August. The price risk minimizing hedge ratios for each of the objective functions was calculated by assuming that actual yields were known with certainty each year when the hedge was placed. This is essentially the same as the hedge ratio that would be optimum for a storage hedge (i.e., final quantity is precisely known at the start of the hedge period). The price risk minimizing hedge ratios were determined with the same numerical simulation procedure used to estimate the other optimum hedge ratios. The optimum hedge ratios for the pure price risk minimizing hedges are also presented in Table 4.

The addition of yield risk causes the optimum futures hedge ratio estimates to change dramatically. This change is due to the decrease in yield risk that occurs over the growing season. Since yield risk is the primary difference between the price risk minimizing hedge ratios and the price and quantity risk minimizing hedge ratios, the large difference between these two types of hedge ratios, when evaluated at planting time, suggests that yield risk has the largest impact on optimum futures positions for hedges placed early in the growing season. As yield risk declines over the growing season, the optimum price and quantity revenue risk minimizing hedge ratio approaches the pure price risk minimizing hedge ratio.

The planting time hedge ratio that minimized all squared deviations from expected revenue (futures objective #1) for Iowa was a short futures position of 27% of expected production. When this hedge position was re-evaluated using August 1 prices and yield estimates, the optimum futures position for the Iowa had increased to a short position of 88% of expected production. The optimum planting time futures position was substantially different than the price risk minimizing position calculated at planting time with the same futures price series. At planting time, the optimum price risk minimizing futures hedge ratio was 96% of cash position for futures objective #1. When evaluated with August 1 prices on the December futures contract, the pure price risk minimizing hedge ratio had changed only slightly to 92% of quantity. Since the pure price risk minimizing hedge ratio was relatively stable from planting time to August, most of the change in the optimum hedge position can be attributed to the changes in the yield risk distribution that occur as the crop matures and becomes less dependent on moisture and other weather conditions.

When options are considered, the results are not as clear. With Iowa average yield data, the optimum options position increases from May to August. Using U.S. yield data results in a small decrease in the optimum options positions between May and August. The price risk minimizing options positions also decrease from May to August. This may be attributable to the different strike prices in effect for hedges placed at the different times. Although at-the-money options premiums were always used, the price levels usually changed between May and August. The optimum options hedge ratios, however, did move closer to the pure price risk minimizing options hedge ratios between May and August. This confirms that the risk minimizing hedge ratio estimates move closer to the price risk minimizing hedge ratio as the growing season progresses, regardless of which direction the hedge ratio estimates happen to move.

Most of the yield risk remaining after August 1 can probably be attributed to yield estimation error and not to any of the risks associated with production (e.g. droughts, floods, or weeds). The residual yield risk remaining after August 1 probably declines only slightly until the crop is actually harvested. The possible exception to this pattern occurs with early frosts, hail damage or wet harvest periods. The change in the hedge ratio estimates, therefore, follow the yield estimation error in some manner and probably approach the price risk minimizing hedge ratios asymptotically as harvest approaches.

Table 2. Summary statistics on county level optimum planting time hedge ratios

Futures objective #1) Minimize all squared deviations from expected revenue

COUNTY	HEDGE RATIO[a]	R^2 [b]
FAYETTE	-.39	23%
CHEROKEE	-.53	60%
JEFFERSON	+.40	9%
CASS	-.26	21%
WARREN	+.15	7%
WEBSTER	-.39	31%
BOONE	-.39	29%

Futures objective #2) Minimize negative squared deviations from expected revenue

COUNTY	HEDGE RATIO[a]	R^2 [b]
FAYETTE	-.41	21%
CHEROKEE	-.63	61%
JEFFERSON	+.38	7%
CASS	-.35	42%
WARREN	+.09	3%
WEBSTER	-.43	31%
BOONE	-.36	22%

Table 2. Continued

Futures objective #3) Minimize all percentage deviations from expected revenue

COUNTY	HEDGE RATIO[a]	R^2 [b]
FAYETTE	-.35	27%
CHEROKEE	-.51	32%
JEFFERSON	-.20	1%
CASS	-.13	7%
WARREN	-.19	2%
WEBSTER	-.51	25%
BOONE	-.41	10%

Options objective #1) Minimize negative squared deviations from minimum revenue

COUNTY	HEDGE RATIO[a]	R^2 [b]
FAYETTE	-.84	58%
CHEROKEE	-1.02	99%
JEFFERSON	-.23	1%
CASS	-.62	98%
WARREN	-.09	3%
WEBSTER	-.92	68%
BOONE	-.82	75%

Table 2. Continued

Options objective #2) Minimize negative percentage deviations from minimum revenue

COUNTY	HEDGE RATIO[a]	R^2 [b]
FAYETTE	-1.13	58%
CHEROKEE	-1.21	88%
JEFFERSON	-.79	7%
CASS	-.81	85%
WARREN	-.25	20%
WEBSTER	-1.17	55%
BOONE	-.94	58%

[a] Short futures positions and long put options positions are indicated by a negative sign preceding the hedge ratio, while long futures positions and short put options positions (puts written) are indicated by positive signs. The hedge ratio is expressed as the percent of expected quantity held in the futures or options markets.

[b] Hedge effectiveness, R^2, is defined as the percentage reduction in the sum of the appropriate deviations resulting from hedging at the specified optimum level.

Table 3. County versus individual farm optimum hedge ratio estimates

	BOONE COUNTY	50 FARMS IN BOONE COUNTY	
	h*[a]	h*[a]	RANGE
FUTURES OBJ. 1	-.39	-.34	+.60 TO -1.45
FUTURES OBJ. 2	-.36	-.46	+.50 TO -1.37
FUTURES OBJ. 3	-.41	-.28	+.90 TO -1.53
OPTIONS OBJ. 1	-.82	-1.19	+.09 TO -2.80
OPTIONS OBJ. 2	-.94	-1.57	-.45 TO -2.90

	WEBSTER COUNTY	50 FARMS IN WEBSTER COUNTY	
	h*[a]	h*[a]	RANGE
FUTURES OBJ. 1	-.39	-.50	+18 TO -.79
FUTURES OBJ. 2	-.43	-.57	+.15 TO -1.01
FUTURES OBJ. 3	-.51	-.54	+.60 TO -1.01
OPTIONS OBJ. 1	-.92	-1.42	-.16 TO -2.90
OPTIONS OBJ. 2	-1.17	-1.60	-.69 TO -2.90

[a] Short futures positions and long put options positions are indicated by a negative sign preceding the hedge ratio, while long futures positions and short put options positions (puts written) are indicated by positive signs. The hedge ratio is expressed as the percent of expected quantity held in the futures or options markets.

Table 4. Planting versus August hedge placement

Futures objective #1) Optimum hedge ratios

PLACED	IOWA	U.S.	PRICE RISK MINIMIZING
MAY	-.27	-.34	-.96
AUGUST	-.88	-.68	-.92

Futures objective #2) Optimum hedge ratios

PLACED	IOWA	U.S.	PRICE RISK MINIMIZING
MAY	-.33	-.47	-1.13
AUGUST	-1.01	-.84	-1.15

Futures objective #3) Optimum hedge ratios

PLACED	IOWA	U.S.	PRICE RISK MINIMIZING
MAY	-.16	-.18	-.95
AUGUST	-.63	-.53	-1.12

Table 4. Continued

Options objective #1) Optimum hedge ratios

PLACED	IOWA	U.S.	PRICE RISK MINIMIZING
MAY	-.69	-.91	-1.85
AUGUST	-.97	-.83	-1.21

Options objective #2) Optimum hedge ratios

PLACED	IOWA	U.S.	PRICE RISK MINIMIZING
MAY	-.75	-1.18	-1.85
AUGUST	-1.25	-1.03	-1.26

CHAPTER 6. CONCLUSIONS

Based on 10 year yield data from a sample of 250 corn farms, a numerical simulation procedure was used to determine the best preharvest futures and options positions for corn producers using several different hedging objectives. Estimates of the optimum hedge ratio based on county average yield data were compared to estimates made with individual farm yields. In addition, changes in the optimum position associated with changes in the distribution of yield risk over the course of the growing season were determined at the state and national level.

Preharvest optimum futures hedge ratios at the farm level vary widely. The majority of farms had an optimum short futures position of 20% to 60% of expected production. The variability of optimum futures positions among farms is partially explained by the correlation between futures price changes and changes in yield expectations over the growing season. Farms that performed well in the drought years, did poorly in years when most farmers experienced bumper crops, or had other unusual yield patterns tended to have atypical optimum positions (i.e., net long positions).

The optimum options positions were often near or above the maximum expected yield for the farm and were generally much larger than the corresponding optimum positions in the futures market. Since overall risk reduction near the optimum options position was insensitive to relatively large changes in the hedge ratio, options positions that were substantially smaller than the precise optimum would have performed adequately for most producers. The risk reducing effectiveness of futures hedges was also not sensitive to moderate changes in the hedge ratio, but futures hedges were more sensitive than the options.

Measures of hedge effectiveness also vary widely across farms. Some farms cannot reduce revenue risk by hedging with either futures or options, while other farms can eliminate almost all revenue risk. As expected, options positions protect against downside risk most effectively. However, measures of hedging effectiveness for both futures and options vary significantly across farms. Comparing the effectiveness of futures versus options hedges is difficult because the two instruments have different underlying purposes. The options are effective at setting a revenue floor, but are not useful for producers who are trying to minimize the variability of revenue. The futures markets are more effective at minimizing deviations from expected revenue, but are not as effective at establishing a revenue floor as the options are.

Hedge ratios estimated with county, state, or national data are not necessarily good estimates of hedge ratios for individual farms. Although the mean hedge ratio of farms within a single county is close to the hedge ratio determined with county level data, there is considerable variation when individual farm hedge ratios are compared to the county hedge ratio estimate. Differences in soil types, drainage, weather, and farming practices cause the optimum hedge ratio at the farm level to be highly variable across farms, even within a single county.

The optimum hedge ratio varies as the growing season progresses and yield risk declines. The optimum preharvest hedge ratio approaches the price risk minimizing hedge ratio as yield risk declines. After the primary weather risk in July has passed, futures positions of slightly less than 100% of anticipated production would minimize revenue risk for most producers. Experienced corn producers should be able to estimate their expected yields at various stages in the growing season with reasonable accuracy and adjust their hedge positions as yield becomes more certain.

The rule of thumb suggesting preharvest futures hedges of 30% to 50% of expected production would have been a reasonable estimate of the optimum hedge ratio for many producers. The distributions of the optimum hedge ratios show that approximately 80% of the optimum futures hedge ratios for Iowa corn producers fell between short futures positions 0 to 80% of expected production. With options hedges, a larger position, possibly 50% to 120% of expected production, would have been needed to minimize downside revenue risk for most producers in Iowa. The distributions also show that some hedgers needed long positions or very large short positions to minimize risk. Simple strategies or rules of thumb are not adequate for these producers and further research is needed to evaluate the appropriate types of futures and options strategies that would best meet their risk management needs.

The crucial element in evaluating preharvest hedging decisions is information on yields and expected yields. In addition to recording their yields, farmers who are serious about developing optimum preharvest hedging strategies also need to record their yield expectations at various stages in the growing season. Additional estimates of expected yields, at several points in the growing season, would further illustrate the effect the changing expected yield distribution has on the optimum hedge ratio estimate. Plant growth models may provide some help in estimating expected yields between planting and harvest, but require site specific weather data. The first source of information on yield expectations needs to be the farmer. Such information would certainly benefit the farmer, and it would greatly aid researchers who are trying to evaluate preharvest hedging decisions.

The analysis does not address whether the revenue or price established by the optimum positions was attractive to farmers. On average, these strategies did increase revenue relative to cash sales at harvest, but they may not have covered costs of production or achieved other revenue goals that might be attractive to producers. In addition, futures and options strategies were considered separately. Further research could be done on preharvest strategies that use combinations of futures and options positions.

The analysis presented in this paper is based on the weather, yield and price patterns that occurred during the 1980s. These results are optimum for future periods only to the extent that yield and price relationships remain similar to those experienced in the 1980s.

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APPENDIX A. DISTRIBUTION OF FARM LEVEL HEDGE RATIOS

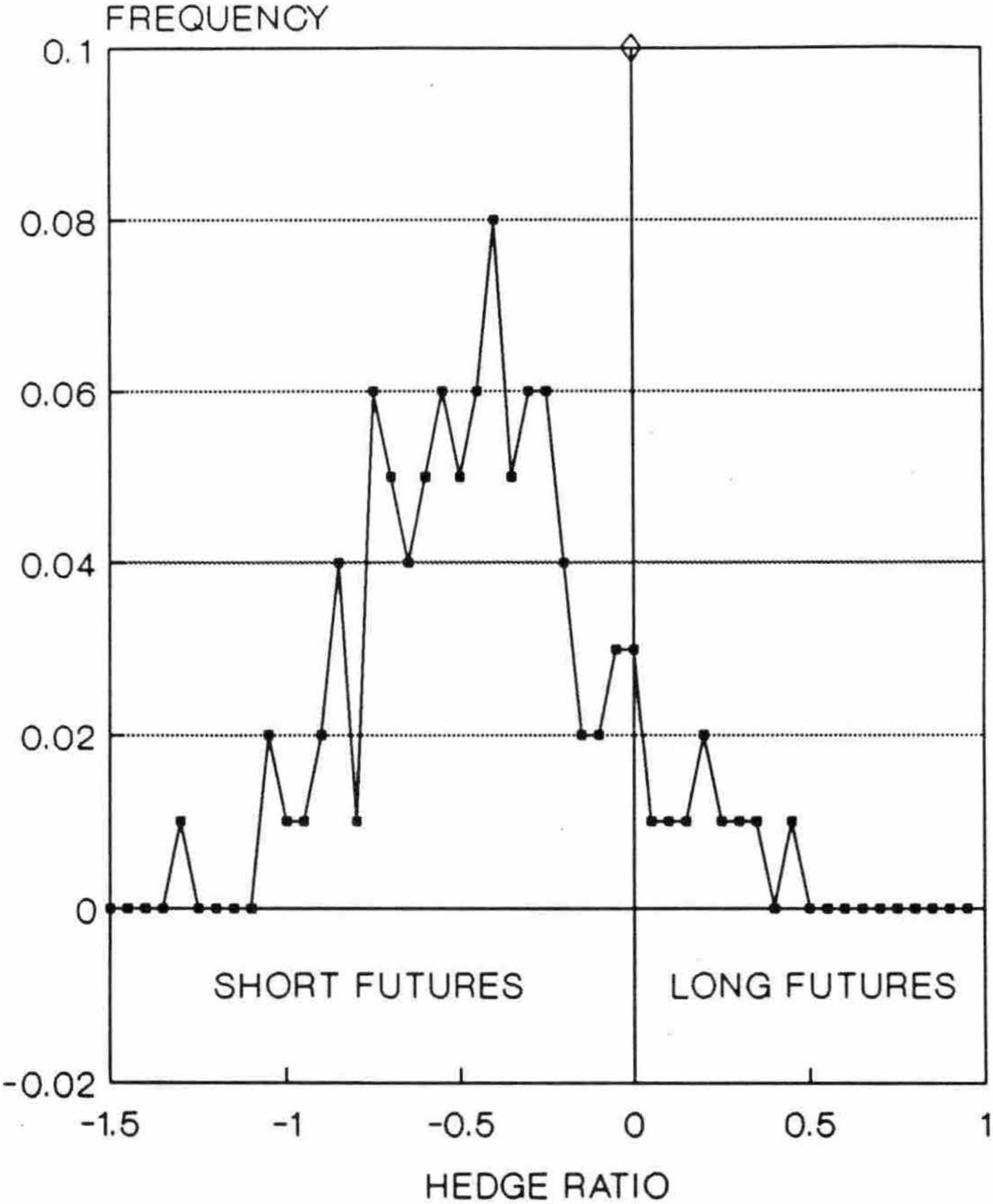

Figure A.1. Distribution of farm level optimum hedge ratios, 1981 - 1989, futures objective #1

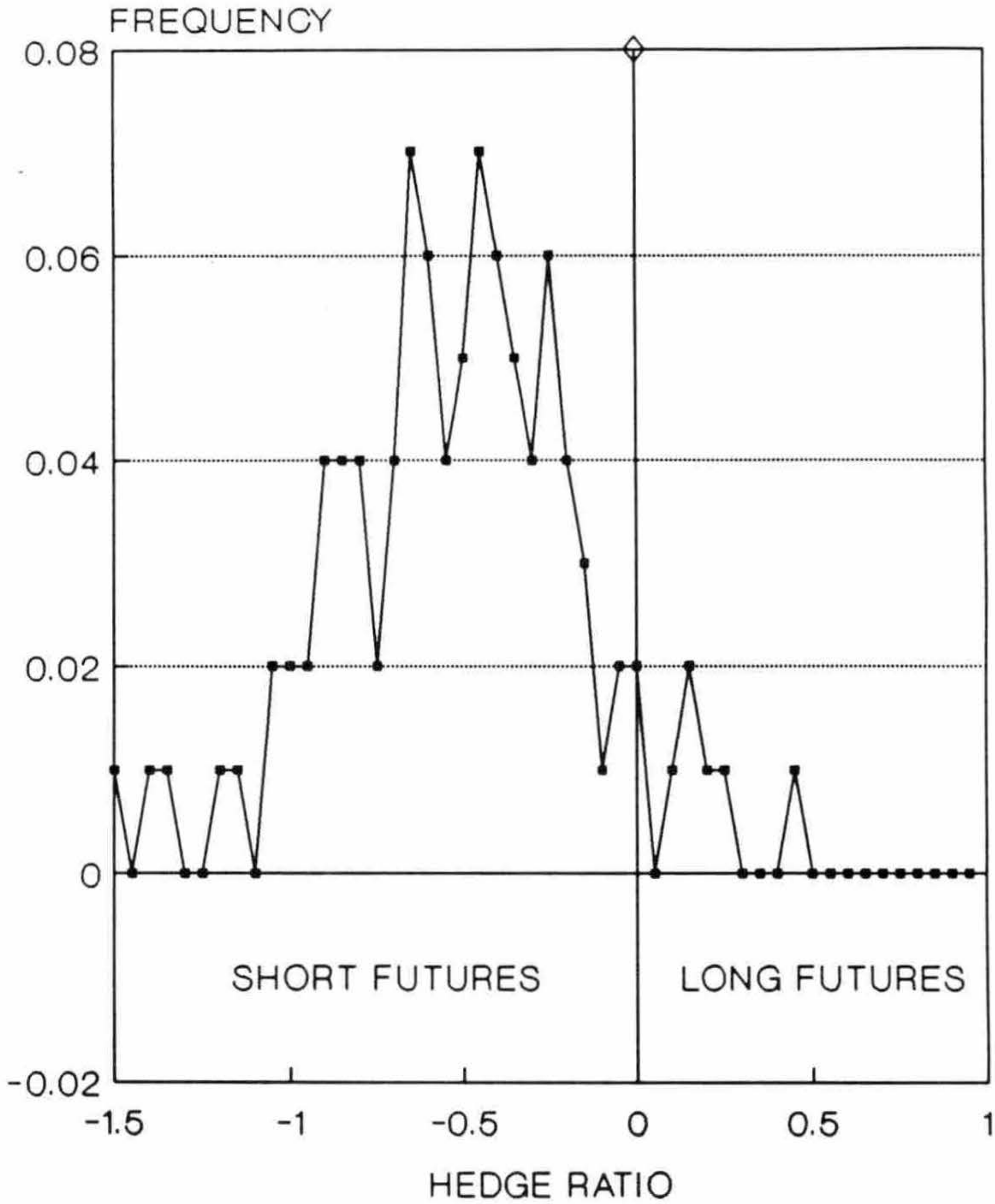

Figure A.2. Distribution of farm level optimum hedge ratios, 1981 - 1989, futures objective #2

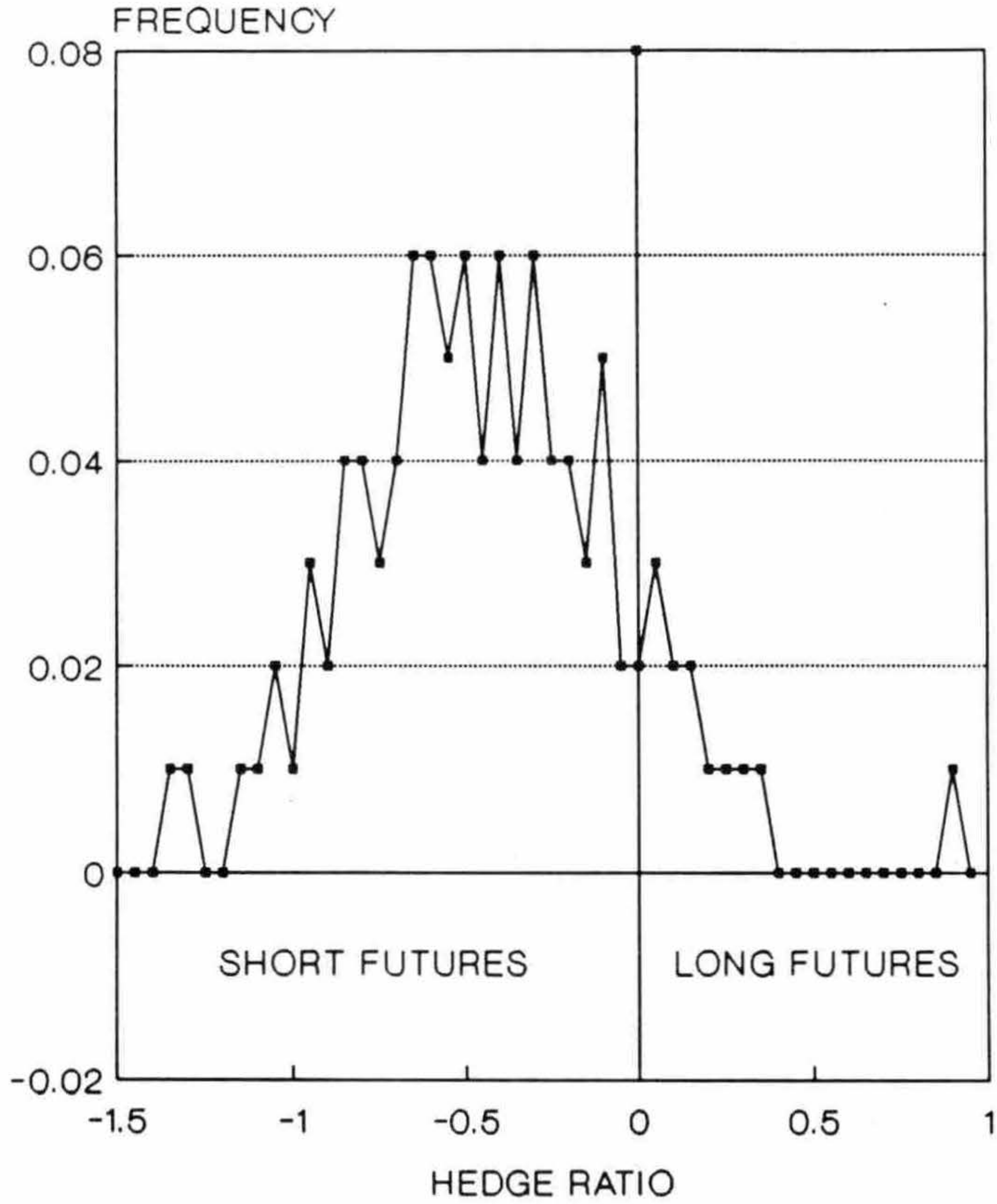

Figure A.3. Distribution of farm level optimum hedge ratios, 1981 - 1989, futures objective #3

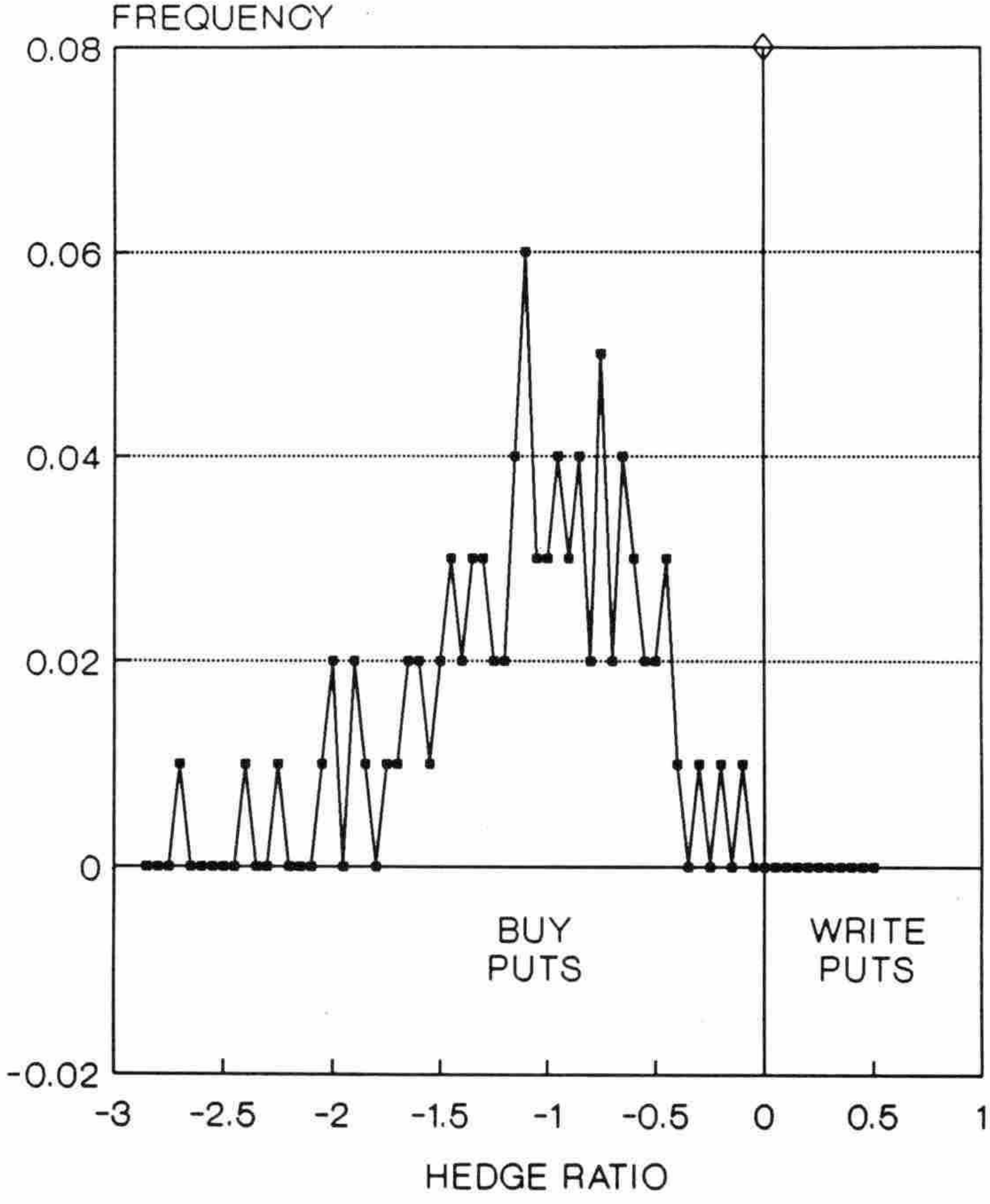

Figure A.4. Distribution of farm level optimum hedge ratios, 1981 - 1989, options objective #1

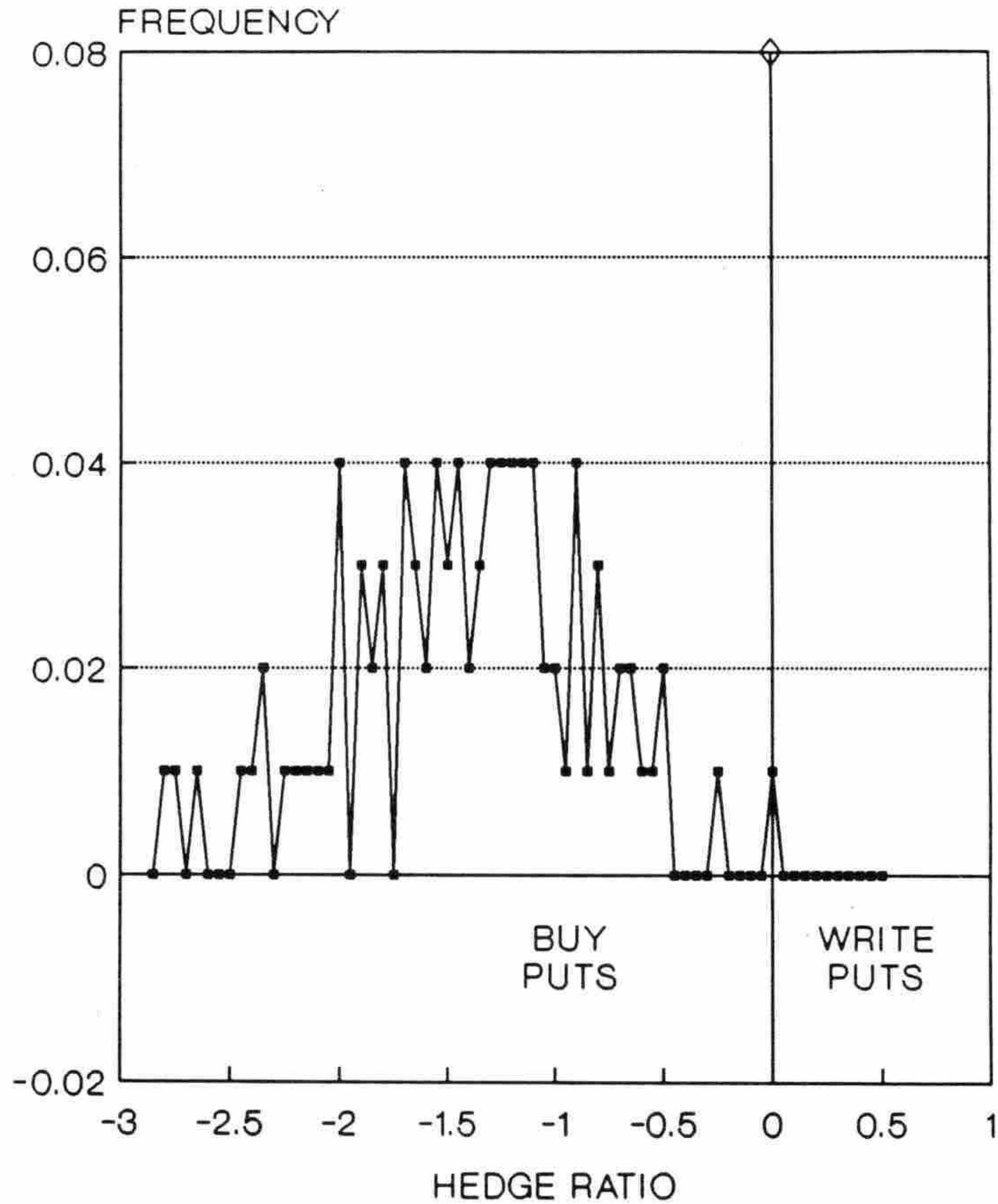

Figure A.5. Distribution of farm level optimum hedge ratios, 1981 - 1989, options objective #2