HEDGING HARD RED WINTER WHEAT:

KANSAS CITY VS. CHICAGO

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PREFACE

This study was conducted to provide new information important to improving the marketing of hard red winter wheat. Traditionally, hedging with the Kansas City Board of Trade is used by marketing firms to exchange price risk for basis risk. These firms may benefit from trading with the Chicago Board of Trade because the transactions costs are less than Kansas City.

The specific objectives of this research are to (a) estimate the regression hedge ratios for the Kansas City and Chicago Boards of Trade contracts for hedges over different time horizons, (b) determine the distributions of returns from hedging with the Kansas City and Chicago contracts, and (c) determine which exchange hedgers should use based on their risk aversion coeficients. Nonlinear regression is used to estimate the hedge ratios and conduct the simulations. A simple utility function is used to calculate the risk aversion coeficients.

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INTRODUCTION

The Hard Red Winter Wheat Industry

Wheat is the most important food grain in the world. It is the leading food crop in acreage and production (Metcalf and Elkins). Hard red winter wheat is the most important of all wheats, comprising about 50% of the total U.S. wheat crop and a major portion of the world's acreage.

The production and marketing of hard red winter wheat is an important industry in the United States. Wheat is the second most valuable crop behind corn. Hard red winter wheat is particularly important in Oklahoma. Oklahoma ranked second in hard red winter wheat production in the United States seven of the last nine years (Oklahoma Agricultural Statistics 1993). Also, wheat production in Oklahoma accounted for 10.7% and 11.8% of total agricultural cash receipts to producers in 1993 and 1992.

History and Development of the U. S. Wheat Market

In colonial America almost all of the people were involved in production of crops and livestock of one kind or another. The major form of marketing during this time was the barter system. This system was characterized by the direct trade of goods for other goods and services. Most communities, and even individuals, were self sufficient in that all the needs of the people were produced in the community or the area immediately surrounding.

As society in America continued to develop, the marketing system began to expand rapidly and become increasingly complex. As people became more interdependent on each other for their needs, the marketing system eventually moved from the barter system to the monetary exchange system we have today. It is in this system that price is the primary means of communication of value to producers and consumers.

Throughout history wheat has been one of the most valuable and widely grown cereal crops (Kaufman). Records indicate that wheat was produced and sold in Massachusetts and Virginia as early as the 1600's. One of the first organized markets was the one located at the east end of Wall Street in 1725. The commodities traded included wheat, tobacco, and slaves. Another early spot market was an exchange formed at the end of Broad Street in 1752 which traded primarily in eggs and butter. These early exchanges were unstable but they did lay the foundation for the commodity exchanges of today (Kaufman).

Chicago developed as another spot market in the early 1830's. As early as 1832 there had been export shipments of beef and pork from Chicago. The first really large commodity shipment happened in 1839 when 1,678 bushels of wheat were shipped by boat from Chicago to Black Rock, New York. Chicago grew rapidly as a grain terminal due to the agricultural wealth of the surrounding area and its immediate access to water transportation. Three main reasons why Chicago was a center for grain were:

1. Grain was shipped to Chicago for reshipment east.
2. Grain was shipped to Chicago for processing.
3. Grain was shipped to Chicago to support livestock feeding.

There were two other major events that help secure Chicago as a major spot market. These were the opening of the Illinois-Michigan Canal, and the extensive development of railroads (Kaufman).

Another major grain market began to evolve roughly about the same time in Kansas City, Missouri. Like Chicago, its location helped secure its role as a major spot market. The Missouri River and the railroad network provides the two main sources of shipment into and out of this market. Located along the eastern edge of the HRW wheat production area Kansas City became the major market for this classification of wheat filling a niche not satisfied by Chicago.

The Kansas City market was first founded by area merchants who organized the Kansas City Board of Trade which was similar in organization to a Chamber of Commerce. The activities of the KCBOT were halted during the Civil War, but were quickly reorganized by the Chamber of Commerce in 1869. At that time the name was changed to Commercial Exchange and represented a variety of business interests.

Along with these major processing and shipment terminals, many country elevators and farmer cooperatives were forming throughout the country. This helped develop the wide spread, highly decentralized cash market present today. Another final important part of the marketing system is the development of the port terminals with ship loading capabilities. These seacoast markets, mostly located along the Gulf of Mexico, are the major export markets for HRW wheat.

The Marketing Channel and Pricing

The organization of the HRW wheat market can be summarized into five main sectors.

1. Production
2. Assembly & Storage
3. Processing
4. Exporting
5. Transportation

Although some of the intermediary steps are sometimes bypassed, wheat produced in the United States is usually sold by producers to country elevators or farmer cooperatives, which in turn sell the grain to larger terminal elevators. Terminal elevators then sell to millers who process the wheat into flour for use by bakeries and cereal manufacturers. Also, terminal elevators sell to port elevators who perform the function of exporting the wheat to other countries. Behind this complex system lies arguably the most important aspect of the marketing system; price. It is through prices that all the aspects of the market are able to coordinate their activities. Prices from the most remote country elevator to the largest terminal elevator are all related by space, time, and form utility.

Another important aspect of price lies in the fact that wheat is a storable commodity. Since wheat is seasonally produced but demand is relatively stable throughout the year, price may reflect an incentive to store wheat for use at a later date rather than selling it at harvest.

Since wheat is a world wide commodity, price is an important communication linkage between importing and exporting countries as well as competing export countries. The price of wheat in the U.S. is affected not only by the supply and demand situation of the U.S. but of the whole world. Case in point, is the Russian grain purchase of 1973-1974 in which the Russians had a wheat failure and bought huge quantities of wheat from the U.S. This had the greatest impact on wheat prices during the last twenty years (Kaufman).

Problem Statement

Firms producing and marketing hard red winter wheat face significant profit risk. For producers the profit risk is due primarily to production and price risk. Other firms' risk, such as millers and exporters, is due mainly to price volatility. Producers use several methods such as irrigation, fertilizer, and crop insurance to reduce production risk. Price risk, on the other hand, may be reduced through the use of forward contracting and hedging with futures contracts and or participating in government programs.

Due to the correlation between cash and futures prices, firms can choose to take offsetting positions in the cash and futures markets. By hedging, firms trade price risk for basis risk which is usually smaller because cash and futures prices move together.

Traditionally, the Kansas City contract is used to hedge hard red winter wheat (HRWW) and Chicago is used to hedge soft red winter wheat (SRWW). The contract specifications for Kansas City and Chicago are presented in tables 1 and 2 respectively. The Kansas City contract allows deliverly of hard red winter wheat only. The Chicago contract allows delivery of both hard- and soft- red winter wheat at par value. Because Chicago allows delivery of hard red winter at par it may also be useful as a hedging tool for hard red winter wheat. Chicago usually trades at a lower price compared to Kansas City because the futures market relfects the cheapest to deliver commodity which is usually soft red winter wheat. The two markets may invert during times when corn becomes expensive relative to wheat because soft red winter wheat has better feed value.

Thompson, Eales, and Seibold show that conducting transactions in the Kansas City futures market is more expensive than in the Chicago futures market. The question then becomes, can hedgers better maximize utility by using Chicago to hedge hard red winter wheat?

Shapiro and Brorsen argue that few farmers use futures markets even though research suggests they should. A possible explanation for this is omission of transactions costs when estimating hedge ratios. Hedge ratios estimated assuming no transactions costs will be larger than what hedgers actually use. Another reason why few producers use futures markets is due to government programs. The government guarantees a minimum price to the farmer which removes a large portion of the price risk. With the new farm bill however, this will change. For the next seven years, farmers will receive a "market transition" payment based on a percentage of their base acreage and established yields. This payment will decrease until the end of the seventh year when it ceases. Once the government safety net is removed, other price

Table 1. Kansas City Hard Red Winter Wheat Futures Contract Specifications

Trading unit	5,000 bushels
Delivery months	March, May, July, September, December
Trading hours	9:30 a.m.-1:15 p.m. central time
Minimum fluctuation	0.25¢ per bushel
Daily price limit	$0.25 per bushel above or below previous day's settlement price.
Position limit	Net 3 million bushels in any one future or in all futures combined. Limits do not apply to *bona fide* hedgers.
Delivery grade	No. 2 Hard Red Winter Wheat is deliverable at par. No. 1 Hard Red Winter is deliverable at a 1.5¢ per bushel premium, and No. 3 Hard Red Winter at a 1.5¢ per bushel discount.
Delivery	Delivery is made via warehouse receipt issued by an exchange-approved elevator in the Kansas City, Missouri-Kansas Switching District.

Table 2. Chicago Wheat Futures Contract Specifications

Trading unit	5,000 bushels
Delivery months	March, May, July, September, December
Trading hours	9:30 a.m.-1:15 p.m. central time
Minimum fluctuation	0.25¢ per bushel
Daily price limit	$0.20 per bushel above or below previous day's settlement price; limit expands by 50% after three successive limit days.
Position limit	Net 3 million bushels in any one future or in all futures combined. Limits do not apply to *bona fide* hedgers.
Delivery grade	No. 2 Soft Red, No. 2 Hard Red Winter, No. 2 Dark Northern Spring, and No. 1 Northern Spring is deliverable at par. No. 1 Soft Red, No. 1 Hard Red Winter, and No. 1 Dark Northern Spring is deliverable at a $0.01 per bushel premium. No. 3 Soft Red, No. 3 Hard Red Winter, No. 3 Dark Northern Spring, and No. 2 Northern Spring is deliverable at a $0.01 per bushel discount. Wheat containing moisture in excess of 13.5% is not deliverable.
Delivery	Delivery is made via a warehouse receipt issued by an exchange-approved elevator in Chicago at par, and in Toledo at a $0.02 per bushel discount.

protection methods such as hedging and forward contracting will become much more important.

Although producers may not use futures directly to hedge their wheat, many forward contract with local grain elevators to reduce price risk. These firms use futures to hedge against unfavorable price movements on their forward contracts; they are not in the business of speculating on the price of wheat. The ability of these firms, with which farmers forward contract, to hedge using Chicago is important because the savings associated with lower hedging costs can be passed on to the producers. Therefore, producers may benefit from this study even if they use only forward contracts.

These larger firms are really the most important aspect of the problem. Thompson, Eales, and Seibold state, "For short-term 'operational' hedges, such as are common for millers, a hedge in Chicago may be preferred since the basis between Kansas City and Chicago may be expected to remain fairly constant over a period of a few days." Large firms trade many thousands of contracts a year and the potential savings in hedging costs that can be obtained through information in this study could be quite large for these firms.

According to Thompson, Eales, and Seibold trading on the Kansas City Board of Trade can be more expensive; from a minimum of $0.54 per contract for the July wheat contract traded in June to $14.01 per contract for the lightly traded September contract traded in February. This is mainly due to market slippage due to low trading volume and the lack of liquidity at Kansas City. N'Zue states that the average weekly volume for Kansas City and Chicago wheat from 1987-1992 was 25,003 and 59,516 contracts respectively. These figures indicate that Chicago trades over twice as many contracts as Kansas City; a large difference in liquidity which validate Thompson, Eales, and Seibold's findings. Thompson, Eales, and Seibold also found a significantly higher transaction cost at Kansas City which is independent of trading volume. If hard red winter wheat could be hedged using the Chicago contract, research suggests hedging costs could be reduced.

The problem for these firms is, due to the lower liquidity costs at Chicago, can they maximize utility by hedging hard red winter wheat using the Chicago contract. In order to hedge on the Chicago Board of Trade, the hedger needs to know how many contracts to trade to minimize price risk. Traditionally, hedgers who use Kansas City to hedge HRWW take an equal and offsetting position in the futures market from their position in the cash market. One bushel of wheat is sold or bought in the futures market for each bushel in the cash market. Since Chicago reflects the cheapest to deliver commodity, soft red winter wheat, the correlation with the HRWW cash market will be less than the correlation between the Kansas City contract and the HRWW cash market. Therefore, if Chicago is used, the number of bushels sold or bought in the futures market is likely to be less than a one-to-one ratio with the number of bushels in the cash market. Trading, including commissions and liquidity, costs will also cause the ratio of futures to cash to be less than one-to-one. Once the ratio of bushels in the futures market to bushels in the cash market is determined, the next problem is to calculate the utility values for Kansas City and

Chicago. These utility values will help hedgers to determine which exchange to use. Once the utility values are determined, they will reveal whether or not the lower liquidity costs at Chicago are low enough to offset Chicago's greater basis risk.

Objectives

The overall objective of this study is to determine if utility is maximized by hedging hard red winter wheat with the Chicago contract versus the Kansas City contract.

The specific objectives are:

1. Estimate the regression hedge ratios for the Kansas City and Chicago Boards of Trade contracts for hedges over different time horizons.

2. Determine the mean returns from hedging with the Kansas City and Chicago contracts.

3. Determine which exchange hedgers should use by maximizing expected utility allowing for transactions costs and five different risk aversion levels.

Summary of Procedures

Regression analysis will be used to determine the static minimum risk hedge ratios for both the Kansas City and Chicago contracts for 1, 5, 10, 21, 65, and, 130 market day hedges. Martinez and Zering, studied dynamic optimal hedging strategies for grain producers with both yield and prices unknown to allow for changes in the hedge position over time. Martinez and Zering note that the small gain in return from dynamic optimal hedging strategies does not justify the much more complicated model. McNew and Fackler found that stochastic hedge ratios are not significantly different from constant hedge ratios.

Because the Chicago contract is not specifically a hard red winter wheat contract, Vukina and Anderson would classify this as a cross hedge; although on the continuum from a straight hedge to a cross hedge, this study would be closer to a straight hedge. All hedges are cross hedges to some degree because of differences in grades, location, and time.

It is common for price levels to be used when empirically estimating hedge ratios. Brown shows, however, that this leads to misspecified hedge ratios. Witt, Schroeder, and Hayenga defend price level regressions stating that the price difference model is prefered only if the order of price differences match the estimated order of autocorrelation. Most hedgers, though, are not so much concerned with the price level, as with the risk of a price change. If hedging is effective it will protect the hedger from changes in the price. Also, this study estimates the higher order autocorrelation coefficients which match the order of price differences. Therefore, price changes are used which will yield better hedge ratio estimates.

After the hedge ratio estimates are calculated, they will be used to conduct nonstochastic hedging simulations for different time horizons on each exchange. The hedging simulations will yield the estimated returns for each time horizon and exchange. Theory states that the expected returns to hedging are zero. Therefore, the estimated hedging returns will be tested to determine if they are significantly different from zero. This will indicate whether the simulated hedges are in agreement with theory.

Finally, transactions costs, including commissions and liquidity costs estimated by Thompson, Eales, and Seibold, are subtracted from the assumed mean hedging returns of zero. Utility function values will be computed for five different levels of risk aversion. This information will be used to determine which exchange hedgers should use based on their risk aversion level.

Thesis Organization

Chapter 2 will describe the theory used to derive the empirical models for the estimation of the hedge ratios and the nonstochastic hedging simulation used to calculate the returns distributions. Also, utility maximization theory will be discussed. Finally, Thompson, Eales, and Seibold's methods are reviewed and market slippage is explained. Chapter 3 will detail the procedures used to estimate the hedge ratios, conduct the simulations, and calculate the utility function values. Also, the data used for the research will be discussed and basis tables are presented. Chapter 4 will provide details of the calculated hedge ratios and the mean returns and their significance, the utility maximizing hedge ratios, and the utility function values. Also, the liquidity costs of each exchange and the relative risk aversion coefficients will be presented. Chapter 5 will summarize the results from chapter 4 and make recommendations for hedging with Kansas City or Chicago based on the hedger's relative risk aversion.

CHAPTER 2

THEORETICAL MODELS

Chapter 1 described the problem and outlined the objectives and procedures. This chapter will discuss the history of hedge ratio estimation and explain the utility maximization theory used to derive the hedge ratios. Thompson, Eales, and Seibold's methods are reviewed and market makers and slippage are discussed.

Hedge Ratio Estimation History

Johnson and Stein introduced the widely used static minimum-variance hedge-ratio model. The static minimum-variance hedge ratio is usually estimated with ordinary least squares (OLS) using price level data. Brown shows, however, that price levels may result in a violation of the assumptions of the OLS model. Lence, Kimle, and Hayenga estimated a dynamic minimum variance hedge model and found that the gains in effectiveness over a static minimum variance model were negligible.

Brorsen (1995) states that the Johnson and Stein (JS) approach and modern versions of the JS approach such as Brown, and Myers and Thompson, estimate hedge ratios near one. One factor that may cause the hedge ratio to be less than one is transactions costs. Research has shown positive returns to scalpers (e.g., Brorsen (1989); Trevino and Martell; Helms and Martell) which suggest that the assumption of no transactions costs is invalid. Also, according to Thompson, Eales, and Seibold, commissions costs can be quite expensive for small off-floor traders. Finally, Howard and D'Antonio show that futures markets provide the service of risk reduction, but impose a cost for this service. Therefore, the optimal hedge ratio will likely be substantially less than one in many cases.

Kahl states that the hedge ratio is independent of risk aversion if both the cash and futures positions are endogenous. This study assumes the cash position is given and therefore optimal hedge ratios depend on the level of risk aversion.

Utility Maximization

Benninga, Eldor, and Zilcha show that mean-variance hedge ratios are consistent with utility maximizing hedge ratios under the following assumptions: (i) the decision maker is not allowed to participate in alternative activities, (ii) no transactions costs, (iii) no production risk, (iv) cash prices are a linear function of futures prices with an independent error term, and (v) futures prices are unbiased. According to Leuthold, Junkus, and Cordier, relaxing (v) results in the following mean-variance utility maximization problem.

(1) $$\text{Max } E(U) = X_s E(\tilde{R}_s) + X_f E(\tilde{R}_f) - \lambda/2(X_s^2\sigma_s^2 + X_f^2\sigma_f^2 + 2X_f X_s \sigma_{sf})$$

where E(U) is expected utility,

X_s is the amount of the cash position,

X_f is the amount of the futures position,

$E(\tilde{R}_s)$ is the expected return on the cash position,

$E(\tilde{R}_f)$ is the expected return on the futures position,

λ is the risk aversion coefficient,

σ_s^2 is the variance of the cash returns (price change),

σ_f^2 is the variance of the futures returns (price change), and

σ_{sf}^2 is the covariance of the changes in futures and cash returns.

As stated above, this study relaxes assumption (ii) rather than (v). They are equivalent, though, if transactions costs are considered to cause the bias in the expected return to the futures position.

Assuming (Max E(U) $\equiv$ Max Z), (1) can be rewritten as:

(2) $$\text{Max } Z = X_s(E(\tilde{S}_1) - S_0) + X_f[(E(\tilde{F}_1) - F_0) - TC] - \lambda/2(X_s^2\sigma_s^2 + X_f^2\sigma_f^2 + 2X_fX_s\sigma_{sf})$$

where S_0 is the cash price at time 0,

$\tilde{S}_1$ is the expected value of the cash price at time 1,

F_0 is the futures price at time 0,

$\tilde{F}_1$ is the expected value of the futures price at time 1 and,

TC is the transactions costs consisting of commissions and liquidity costs.

Taking the first derivative of (2) w.r.t. X_f yields:

(3) $$\partial Z / \partial X_f = [(E(\tilde{F}_1) - F_0) - TC] - \lambda X_f\sigma_f^2 - \lambda X_s\sigma_{sf} = 0 \; .$$

Rearranging the above expression yields:

(4) $$X_f = \{[(E(\tilde{F}_1) - F_0) - TC] / \lambda\sigma_f^2\} - [X_s(\sigma_{sf}/\sigma_f^2)]$$

which yields the futures position at a specified risk aversion level and allowing for transactions costs.

Applying the assumptions that firms do not speculate on the price in the future and zero transaction costs, the first part of (4) above goes to zero and the minimum risk hedge ratio can be expressed as:

(5) $$X_f^* = -X_s(\sigma_{sf}/\sigma_f^2)$$

The cash position is assumed to be exogenous, so let $X_s = 1$ and let $b = -X_f/X_s$.

Now, b^*, the minimum risk hedge ratio is:

(6) $$b^* = \sigma_{sf}/\sigma_f^2$$

In OLS regression the coefficient $\beta = \sigma_{sf}/\sigma_f^2$. This leads to the regression equation

(7) $$(Cash_t - Cash_{t-k}) = \alpha_0 + \alpha_1(KCfut_t - KCfut_{t-k})$$

for Kansas City and

(8) $$(Cash_t - Cash_{t-k}) = \gamma_0 + \gamma_1(CHfut_t - CHfut_{t-k})$$

for Chicago

where $Cash_t$ - $Cash_{t-k}$ is the cash price difference from day t to day (t - k),

and $Futp_t$ - $Futp_{t-k}$ is the futures' price difference from day t to day (t - k).

This will yield estimates of the hedge ratios for each exchange and their respective hedging effectiveness.

Utility Maximizing Hedge Ratios and Risk Aversion

The hedge ratios calculated from (5) assume transactions costs to be zero. This leads to higher hedge ratios than is realistic. Therefore, by substituting the hedge ratios estimated in (5) back into the second term in (4) and assuming some level of transactions costs and level of risk aversion yields the utility maximizing hedge ratios. The level of transactions costs in (4) consist of commissions and liquidity costs.

Utility maximizing hedge ratios from (4) are computed for five levels of the Pratt-Arrow risk aversion measure ranging from 0.0001 which is almost risk neutral to 1.0 which is extremely risk averse. The risk aversion coefficient places a negative weight on the variance of returns. As the risk aversion level or the variance of returns increases, the expected returns are discounted which results in a lower utility value. A weight of 0 is termed risk neutral. Hedgers who are risk neutral would choose the hedge ratio with the highest expected returns regardless of the variance of those returns. A weight of 1, in this case, is considered extremely risk averse. A hedger with this level of risk aversion would choose a hedge ratio with a very small variance of returns even if the expected returns are less.

Raskin and Cochran state that their is little consistency on appropriate coefficients or classifications of values, and further, that most risk aversion coefficients are assumed. This study chooses the range above because it represents levels from almost risk neutral, where the cash is prefered to hedging, to extremely risk averse where the utility maximizing hedge ratios in (4) converge to the minimum risk hedge ratios estimated in (5).

King and Robison show that the Pratt-Arrow measure is invariant to liner tansformations. Raskin and Cochran state, however, that this is not true over varing temporal or spatial scales. In this study risk aversion coefficients' units are in hundreths of cents. Therefore, care must be taken to transform them to the appropriate units when comparing these risk aversion levels to other studies. Also, the risk avesion levels are not directly comparable between different hedge periods in this study because of the temporal shift. They are, however, comparable across exchanges within the same hedge period.

Market Makers and Slippage

Market makers is a term that applies to a party who is willing to take an opposite position of a buy or sell transaction. Market makers are important to providing a liquid market. If there are not many willing to take the other side of a trade, it will be difficult to transact in the market. In addition, the greater the number of market makers the less expensive it is to transact because of competition. This transaction expense is called slippage and refers to the difference between where an order was placed and where it was filled. For instance if someone places an order to sell at \$4.500 and the order is filled at \$4.495, the slippage is equal to \$0.005.

Thompson, Eales, and Seibold measured this slippage in the Kansas City and Chicago wheat futures contracts. She found that the slippage was greater in Kansas City than in Chicago. Another common term for slippage is the bid-ask spread. Because the bid-ask spread is not recorded on the exchanges, Thompson uses two established methods (Roll's measure and the Thompson-Waller proxy) to approximate the bid-ask spread. The data used are seven sets of intra-day price tick observations where a tick is one-quarter of a cent. An area of caution that Thompson notes is that the data are from only one short time period which could make the results peculiar to this time period. However, the results were consistent with those found by Thompson and Waller for corn and oats.

In order to obtain robust results, this study takes the low and high liquidity costs (market slippage) for Chicago and Kansas City estimated in Thompson's work, adds them to commssions costs for producers and commercial firms, and computes hedge ratios for producers and commercial firms under each scenario. If it is determined that Chicago would not be used even with the highest liquidity cost difference, we can conlcude that Kansas City is preferred over Chicago.

CHAPTER 3

DATA AND PROCEDURES

Chapter 2 explained the theory used to derive the models used in this study. This chapter will explain the procedures used to estimate the hedge ratios, compute the mean hedging returns, and compute the utility function values. The data used for this study is also discussed.

The Data

Time Period of Data

Daily price series data were collected for the cash and futures prices. The daily closing prices of each contract month for both the Kansas City and Chicago Boards of Trade were collected from January 1, 1986 through May 31, 1994 (Technical Tools). The cash prices are the Texas Gulf daily closing prices collected over the same time period (Oklahoma Market Report). Data before 1986 was excluded due to possible structural changes in the market due to the payment in kind (PIK) program and the export enhancement program (EEP).

This research assumes the time period from Friday to Monday to be one day; hence the term market day. Weekends are ignored since no trading takes place on these days which results in a continuous 5 day week data set. Also, holidays on which trading did not occur are ignored. This results, at times, in a jump from Friday to Tuesday in the case of a Monday holiday. Hedge ratios are calculated for 1, 5, 10, 21, 65, and 130 market day hedge periods. This corresponds to 1 day, 1 week, 1 month, 3 month, and 6 month calendar hedge periods and therefore provides a good distribution of short- and long-duration hedges. All hedge periods, use the closest futures contract month beyond the month in which the hedge is to be exited. For instance, one day hedges exited in May and June will use the July futures contract. Then on the first one day hedge to be exited in July, the futures contract month is rolled from the July contract to the September contract.

Hedge Ratio and Simulation Data

To estimate the hedge ratios and conduct the hedging returns simulations a data set for each hedge period and exchange was constructed from the raw data. This data set included variables for the following: enter and exit dates, exit month, exit contract month, and an enter and exit price for both the cash and futures markets. The futures contract month used is the nearby contract as stated above. This avoids anomalies during the expiration month of a futures contract. For example, a one month hedge initiated on June 15th and exited on July 15th will use the closing September futures contract price on June 15th for the enter futures price and the closing September futures contract price on July 15th for the exit futures price. The enter and exit cash prices are the Texas Gulf bid on June 15th and July 15th respectively.

Basis Tables

The mean and standard deviations of the basis of each contract month observed in each calendar month for each exchange are presented in tables 3 and 4. Table 3 presents the basis values for the Kansas City Board of Trade while table 4 presents the basis values for the Chicago Board of Trade. These basis levels and standard deviations are very important because hedgers exchange price risk for basis risk. By examining the tables, a hedger can determine within a range where a basis level is likely to vary. If the situation allows, a hedger would choose a contract month and calendar month in which there is a relatively small deviation from the mean. This will provide the least basis risk.

Notice that the mean basis levels for Chicago are smaller than for Kansas City. The reason for this is that the Kansas City wheat price is on average higher than the Chicago wheat price and the same spot market is used for each exchange. Although the target price of a hedge using Chicago would likely be higher, the standard deviation of a hedge in Chicago is also much larger. This means that although the hedger is getting a better target price, they are taking on more basis risk as well. Finally, it is not the price level that a hedger is concerned with as much as the price change that could occur over a period of time.

OLS Hedge Ratios

The OLS procedure in Shazam was used to estimate the minimum risk hedge ratios discussed in chapter 2. For each hedge period the change in the futures contract price is regressed against the change in the gulf cash price for the period

Table 3. Kansas City Board of Trade Hard Red Winter Wheat Contract Average Basis for 1986-1994

Contract Month	Calendar Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mar	46.0	44.8	44.1	51.5	36.7	23.9	23.4	24.8	32.6	35.8	40.9	45.8
	(8.5)	(7.8)	(18.7)	(28.6)	(15.9)	(9.0)	(9.6)	(10.2)	(11.5)	(12.4)	(10.3)	(8.4)
May	58.6	56.7	57.1	55.9	38.4	30.7	30.0	31.2	39.6	44.7	50.7	57.6
	(14.6)	(14.2)	(14.8)	(16.8)	(13.7)	(12.3)	(14.1)	(12.8)	(14.6)	(16.4)	(15.5)	(15.9)
Jul	72.7	67.1	69.5	66.8	51.5	40.3	40.1	41.8	51.6	57.1	62.7	72.6
	(22.4)	(20.2)	(26.0)	(27.1)	(14.8)	(6.1)	(12.2)	(20.4)	(22.3)	(23.4)	(22.8)	(23.9)
Sep	69.4	63.4	65.6	62.8	47.6	35.9	36.3	38.7	44.5	55.4	58.8	69.1
	(23.2)	(20.8)	(26.6)	(27.9)	(15.8)	(7.9)	(7.1)	(7.6)	(15.2)	(23.0)	(22.9)	(24.3)
Dec	59.8	54.9	57.4	54.4	39.6	26.8	26.8	29.3	35.5	38.1	40.9	43.3
	(23.0)	(20.1)	(25.9)	(28.0)	(15.3)	(7.8)	(8.3)	(9.8)	(9.8)	(9.2)	(6.9)	(11.8)

Note: Standard Deviations are presented in parentheses.

Table 4. Chicago Board of Trade Wheat Contract Average Basis for 1986-1994

Contract Month	Calendar Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mar	39.1	40.3	45.1	48.6	34.2	23.5	21.0	21.8	27.8	30.2	35.5	40.7
	(13.7)	(13.7)	(24.0)	(30.6)	(18.3)	(11.5)	(12.2)	(12.0)	(13.3)	(15.4)	(14.9)	(15.7)
May	53.6	52.4	54.1	51.7	36.5	31.5	29.1	29.5	36.8	40.6	47.1	53.8
	(17.5)	(15.0)	(15.1)	(18.7)	(20.2)	(14.0)	(15.2)	(14.9)	(15.7)	(18.0)	(19.0)	(20.5)
Jul	72.4	66.6	70.2	66.8	53.5	42.2	40.1	42.8	52.0	57.2	63.3	72.7
	(25.1)	(22.5)	(26.2)	(27.7)	(17.4)	(11.8)	(17.3)	(22.6)	(23.6)	(24.5)	(25.9)	(26.7)
Sep	69.3	62.8	65.9	62.2	48.5	37.1	35.1	38.0	44.4	53.4	59.2	68.8
	(25.4)	(22.5)	(26.9)	(28.6)	(18.3)	(11.6)	(12.1)	(12.1)	(17.8)	(24.1)	(25.7)	(26.5)
Dec	59.5	52.8	56.0	52.3	38.1	26.8	24.3	26.3	31.6	32.4	38.1	46.7
	(25.6)	(22.8)	(27.4)	(29.2)	(17.9)	(11.0)	(11.4)	(11.7)	(12.8)	(16.0)	(17.1)	(23.7)

Note: Standard Deviations are presented in parentheses.

being examined. The OLS equation can be written as

(9) $$CASHDIF = \beta_0 + \beta_1(FUTDIF)$$

This yields the linear regression hedge ratios for each hedge period along with the effectiveness of the hedge. Hedge ratios are computed for both the Kansas City and Chicago Boards of Trade.

Nonlinear Hedge Ratios

Correction for Autocorrelation

Since time series data is used for this research first order autocorrelation is expected. Also, due to overlapping time periods, a higher order moving average process equal to the length of the hedge period should be present since the change in price from day t to day (t - k) is equal to the sum of daily price changes over the same (t - k) period. The moving average process is corrected by approximating it as an autoregressive process of an order equal to the length of the hedge period.

Autocorrelation causes inefficiency, biased estimates of the variance, and invalidates hypothesis tests. Therefore, a method must be used to correct for autocorrelation in order to do valid hypothesis testing. Another problem is heteroskedasticity in the error terms due to overlapping data and the cyclical periods of high and low volatility in the wheat futures contract. Finally, the autocorrelation was particularly troublesome because the contract month changes throughout the data, and the autocorrelation function is not of the same order across these changes. The AUTO command in Shazam was considered to correct for this problem. It uses the Cochrane-Orcutt procedure which uses least squares with data transformed by an estimated autoregressive process. The fault with this method is that there is no way to address the problem of contract month changes. To solve this problem nonlinear least squares is used to estimate the autocorrelation coefficient ρ as a parameter in the model. A dummy variable which turns the autocorrelation function off across contract month changes was added in order to correct for it properly. This yields the nonlinear least squares model:

$$
\begin{aligned}
CASHDIF &= \beta_0 + \beta_1 (FUTDIF) \\
&+ \rho_1 [(L_1 CASHDIF) - \beta_0 - \beta_1 (L_1 FUTDIF)] * DUMCH \\
&+ \rho_n [(L_n CASHDIF) - \beta_0 - \beta_1 (L_n FUTDIF)] * DUMCH
\end{aligned} \tag{10}
$$

where *CASHDIF* is the difference in the cash price over the hedge period,

FUTDIF is the difference in the futures contract price over the hedge period,

$L_1CASHDIF$ is the *CASHDIF* lagged once,

$L_1FUTDIF$ is the *FUTDIF* lagged once,

$L_nCASHDIF$ is the *CASHDIF* lagged n times corresponding to the length of the hedge period,

$L_nFUTDIF$ is the *FUTDIF* lagged n times corresponding to the length of the hedge period,

ρ_1 is the first order autocorrelation parameter,

ρ_n is the nth order autocorrelation parameter where n is equal to the hedge period,

and DUMCH is a dummy variable equal to 0 when the contract month changes and 1 otherwise.

Nonlinear least squares estimation in Shazam requires starting values for all parameters in the model. The constant and hedge ratio parameters were obtained from the results to the OLS estimation in (9) and 0 was used as the starting values for the autocorrelation coefficients.

Estimated Generalized Least Squares (EGLS)

The process used to correct for autocorrelation and heteroskedasticity is feasible generalized least squares. The three steps to the process are: (i) estimate 10 above with nonlinear least squares, (ii) estimate a GARCH (1,1) for the residuals of (i) with maximum likelihood estimation, and (iii) estimate (10) above with weighted nonlinear least squares.

The model in (10) above corrects for autocorrelation but the problem of heteroskedasticity remains. The parameter estimates will be unbiased but inefficient. Because this is time series the variance equation was estimated as a GARCH (1,1) model using feasible generalized least squares.

Taking the error term from (10) above, the GARCH (1,1) model is defined as

$$\epsilon_t = \sqrt{h_t}\, e_t$$

(11) $$h_t = \omega + \epsilon_{t-1}^2 + \gamma h_{t-1}$$

$$e_t \sim N(0,1) \;.$$

Bollerslev introduced the GARCH model as a generalization of the ARCH model introduced by Engle.

The residuals and standardized residuals of the GARCH (1,1) model were saved and a weight variable was calculated as follows

(12) $$WT = (\hat{\varepsilon}_t / \sqrt{\hat{h}_t}\,) \,/\, \hat{\varepsilon}_t$$

simplifying (12) yields:

(13) $$WT = 1 / \sqrt{\hat{h}_t}$$

Equation (10) was then multiplied by the weight variable which will cause small variances to have more effect and large variances to have less effect, thereby correcting for a heteroskedastic error term. This yields:

(14)
$$\begin{aligned} WT * CASHDIF = [\![\beta_0 + \beta_1(FUTDIF) \\ + \rho_1[(L_1CASHDIF) - \beta_0 - \beta_1(L_1FUTDIF)] * DUMCH \\ + \rho_n[(L_nCASHDIF) - \beta_0 - \beta_1(L_nFUTDIF)] * DUMCH]\!] * WT \end{aligned}$$

where WT is the weight variable

The parameter estimates yielded by (14) are now unbiased and efficient.

Hedging Simulations

Now that the proper hedge ratios have been estimated the next step is to use these ratios in simulations to determine the distributions of hedging returns. The hedging returns were computed as follows

(15) $$R = (CASH_t - CASH_{t+k}) + RAT(FUT_{t+k} - FUT_t)$$

where R are the returns to the hedge,
$CASH_t$ is the cash price at time t,
$CASH_{t+k}$ is the cash price at time t+k where k is the length of the hedge period,
FUT_t is the futures price at time t,
FUT_{t+k} is the futures price at time t+k where k is the length of the hedge period,
and RAT is the estimated hedge ratio.

Notice that (15) is the equation for a long hedge and the returns for a short type hedge would be opposite of the results generated by (15). The method of using estimated hedge ratios for the simulations is called the plug-in method. According to Lence and Hayes estimation risk occurs when parameters relevant for decision making are uncertain and there are few sample observations relative to the number of activities. They note that the Bayes criterion is consistent with expected-utility maximization. Also, they note that the differences between the Bayes' and the plug-in approach disappear rapidly as the number of observations increase to around 25. Since the least number of observations in this study are 1994 it is obvious that the plug-in approach can be and is used for its ease of computation.

After the returns are calculated in (14) the STAT command in SHAZAM is used to compute the mean, variance, and standard deviation of the hedging returns. The calculated means appear to be different from zero but, by definition, the perfect hedge will result in an expected return of zero. In order to compute the risk aversion coefficients presented later it is important to know if the mean returns to these hedges are really different from zero or can be assumed to be zero.

Again, because this is time series data, autocorrelation will be present in the returns. In order to test the hypothesis of zero mean returns a method must be used to correct for autocorrelation. The NL procedure in SHAZAM is used to regress the lagged returns against the returns to determine if the mean returns (the constant) are significantly different from zero. The nonlinear equation is

(16) $$R = \beta_0 + \rho_1 (L_1 R)\ (DUMCH) + \rho_n (L_n R)\ (DUMCH)$$

where R are the hedge returns,
β_0 is the constant (mean hedge returns),
ρ_1 is the first order autocorrelation coefficient,
ρ_n is the nth order autocorrelation coefficient,
L_1R is the first lag of the returns,
and L_nR is the nth lag of the returns.

If the constant (β_0) is significant in the above equation, this indicates that the returns are different from zero.

Utility Maximizing Hedge Ratios

The hedge ratios estimated using (14) above assume no transactions costs. As stated earlier this leads to unrealistically high hedge ratios. There are two main components to the cost of trading on the futures market. One is liquidity costs as discussed in Thompson, Eales, and Seibold and the other is commissions costs. Liquidity costs are defined as the difference between prices quoted by "market makers" who are willing to take the opposite position of a buy or sell order. Commissions costs include brokers fees, exchange and clearing house fees, and regulatory fees. Liquidity costs are close to the same for small and large hedgers. Transactions costs, on the other hand, vary substantially between producers and large commercial firms.

According to Thompson, Eales, and Seibold commissions costs for small off-floor traders may be as high as $80.00 per contract. Commissions costs for large firms, such as elevators, who have direct access to floor traders are considerably less. This difference in costs has a large impact on how risk averse a firm must be before it prefers a hedge to the cash market. Small hedgers' (producers) commissions costs were assumed to be $80.00 per contract and large hedgers' commissions costs were assumed to be $9.00 per contract.

By using the minimum risk hedge ratios estimated in (14) and the trading costs estimated by Thompson, Eales, and Seibold into (4) from chapter 2, hedge ratios that allow for transactions costs can be calculated. Since (4) requires some level of risk aversion in order to compute the hedge ratio, this study computes hedge ratios for five levels of risk aversion ranging from almost risk neutral (0.0001) to extremely risk averse (1.0). Hedge ratios for producers and commercial firms under low (0.26308¢/bu. for Kansas City and 0.25232¢/bu. for Chicago) and high (0.54189¢/bu. for Kansas City and 0.26164¢/bu. for Chicago) liquidity costs are computed using (4).

Utility Function Values

After the hedge ratios allowing for transactions costs were calculated using (4) above, the next step is to compute the utility function values. Utility values are calculated by using the new hedge ratios, the transactions costs, and the level of risk aversion into the utility function specified in (1) of chapter 2. This will give a value of utility for each hedge period and each exchange for five levels of risk aversion. The task then is to choose the higher utility value between Kansas City and Chicago. The difference in the utility levels should also be calculated to determine the break even level of liquidity cost difference between Kansas City and Chicago.

CHAPTER 4

EMPIRICAL RESULTS

This chapter will present basis tables for the Kansas City and Chicago contracts. The results for the ordinary least squares and nonlinear least squares hedge ratios, the profit simulations and hypothesis tests, and the hedge ratios allowing for transactions costs as well as the utility function values will also be presented.

Minimum Risk Hedge Ratios

Ordinary Least Squares Hedge Ratios and Effectiveness

OLS was used in Shazam to compute the hedge ratios for Kansas City and Chicago. These are minimum risk hedge ratios and assume no transactions costs. The results for Kansas City and Chicago are presented in tables 5 and 6 respectively.

Kansas City results. The hedge ratios for Kansas City ranged from 1.0107 for a one day hedge to 1.1777 for a 6 month hedge. This means that for every bushel in the cash market a hedger would hedge 1.0107 bushels in the futures market for a one day hedge. These results indicate that a hedger would over hedge slightly. The reason for this is that cash market prices are more volatile than futures market prices. Hedging effectiveness for Kansas City ranged from 81.01% to 71.75% for a 6 month hedge and a one month hedge respectively. This means that by hedging you will

Table 5. OLS Hedge Ratios and Hedging Effectiveness: Kansas City Board of Trade

Variable	1 Day Coefficient	5 Day Coefficient	10 Day Coefficient	21 Day Coefficient	65 Day Coefficient	130 Day Coefficient
α_0 (Constant)	0.0006 (1.54)	0.0027* (2.73)	0.0047* (3.21)	0.0082* (3.47)	0.0296* (6.31)	0.0508* (8.35)
α_1 (Hedge ratio)	1.0107* (93.71)	1.0336* (87.24)	1.0179* (80.75)	1.0093* (73.09)	1.1426* (76.32)	1.1777* (92.21)
R^2 (Hedge effectiveness)	0.8053	0.7822	0.7552	0.7175	0.7388	0.8101

Note: The t-values for the test statistics are presented in parentheses and asterisks denote significance at the 5% level.

Table 6. OLS Hedge Ratios and Hedging Effectiveness: Chicago Board of Trade

Variable	1 Day Coefficient	5 Day Coefficient	10 Day Coefficient	21 Day Coefficient	65 Day Coefficient	130 Day Coefficient
α_0 (Constant)	0.0003 (0.51)	0.0013 (1.03)	0.0027 (1.45)	0.0061* (2.16)	0.0316* (6.15)	0.0645* (9.54)
α_1 (Hedge ratio)	0.7970* (63.57)	0.8228* (59.61)	0.8313* (57.52)	0.8887* (56.75)	1.1290* (67.52)	1.1972* (81.17)
R^2 (Hedge effectiveness)	0.6558	0.6267	0.6104	0.6052	0.6891	0.7678

Note: The t-values for the test statistics are presented in parentheses and asterisks denote significance at the 5% level.

reduce your risk of a price change by 81.01% for a 6 month hedge.

Chicago results. The hedge ratios for Chicago are significantly smaller than for Kansas City. This is because the Chicago contract is not solely a hard red winter wheat contract and therefore is less correlated with the cash price. The effectiveness of hedging with Chicago is also less than with Kansas City. This again is due to the lower correlation with the cash market when compared with Kansas City. An interesting anomaly in the results for Chicago is the ratios for 3 month and 6 month hedge periods. The hedge ratios increase substantially over the shorter term hedge periods. Also, the 6 month hedge ratio for Chicago is 1.1972 which is higher than the Kansas City hedge ratio of 1.1777. However, the effectiveness of the hedge (76.78%) is still less than Kansas City's which is (81.01%).

Nonlinear Hedge Ratios

The ordinary least squares (OLS) hedge ratios estimated above are simple but are only valid under the strict assumptions of the OLS model. With the time series data used in this study, the assumptions of no autocorrelation and homoskedasticity are violated. These violations cause inefficient estimates and make hypothesis testing invalid. A weighted nonlinear least squares model is used to re-estimate the hedge ratios correcting for autocorrelation and heteroskedasticity. This model still assumes no transactions costs however, which will be discussed later.

Kansas City nonlinear hedge ratios. The nonlinear hedge ratios for Kansas City are presented in table 7. The estimates are very close to the OLS estimates as they should be since autocorrelation and heteroskedasticity do not cause biased

Table 7. Nonlinear Hedge Ratios and Autocorrelation Coefficients: Kansas City Board of Trade

Variable	1 Day Coefficient	5 Day Coefficient	10 Day Coefficient	21 Day Coefficient	65 Day Coefficient	130 Day Coefficient
α_0 (Constant)	-0.0006 (1.80)	-0.0022 (1.85)	-0.0092* (4.34)	-0.0174* (5.52)	0.0291* (4.87)	0.0581* (8.36)
α_1 (Hedge ratio)	1.0119* (132.31)	1.0180* (136.82)	1.0155* (131.40)	1.0002* (110.65)	1.0380* (78.92)	1.0875* (79.54)
rho_1 (1st order autocorrelation)	0.0439 (0.06)	0.8643* (55.62)	0.9360* (86.28)	0.9626* (116.68)	0.9911* (185.97)	0.9888* (226.56)
rho_n[a] (Nth order autocorrelation)		-0.1311* (9.26)	-0.0722* (7.34)	-0.0226* (3.31)	-0.0109* (2.14)	-0.0058 (1.24)

Note: The t-values for the test statistics are presented in parentheses and asterisks denote significance at the 5% level.
[a] rho_n is the nth order autocorrelation parameter where n is the number of days in the hedge period.

results. The only two that change significantly are the 3 and 6 month hedge ratios. These ratios went from 1.1426 and 1.1777 for the OLS estimates to 1.0380 and 1.0875 for the nonlinear estimates. This is a 10.46% and 9.02% decrease in the 3 and 6 month hedge ratios from OLS to nonlinear estimates. This is due to the extreme autocorrelation present in the longer hedge periods. Efficiency increased greatly for all estimates as indicated by the t-values. Notice also, that the autocorrelation parameter estimates are all significant except for 1st order in the one day hedge, in which there is no overlap of data, and 130th order in the 6 month hedge, in which there is little left to worry about which is indicated by the rho coefficient being close to zero.

Chicago nonlinear hedge ratios. The nonlinear hedge ratio estimates for Chicago are presented in table 8. The results here are much the same as for Kansas City. The parameter estimates, however, did change more than they did in the Kansas City results. Efficiency increased for all but the 3 and 6 month hedge ratio estimates. The nonlinear estimates for the 3 and 6 month hedge ratios are much more believable than the OLS results. The 3 and 6 month hedge ratios are 0.9313 and 1.0199, down from the OLS estimates by 19.77% and 17.73% respectively. The nonlinear estimates seem much more aligned with what would be expected from theory. As with Kansas City, all the autocorrelation coefficients are significant except for 1st order in the one day hedge and 130th order in the 6 month hedge.

Table 8. Nonlinear Hedge Ratios and Autocorrelation Coefficients: Chicago Board of Trade

Variable Coefficient	1 Day Coefficient	5 Day Coefficient	10 Day Coefficient	21 Day Coefficient	65 Day Coefficient	130 Day
α_0 (Constant)	-0.0009 (1.95)	-0.0041* (2.33)	-0.0097* (3.36)	-0.0172* (3.86)	0.0367* (5.19)	0.0683* (7.66)
α_1 (Hedge ratio)	0.7636* (68.00)	0.7871* (74.79)	0.7795* (71.94)	0.7836* (65.72)	0.9313* (61.55)	1.0199* (67.33)
rho_1 (1st order autocorrelation)	0.0307 (0.043)	0.8536* (59.93)	0.9259* (91.34)	0.9663* (121.58)	0.9934* (187.02)	0.9910* (244.98)
rho_n^a (Nth order autocorrelation)		-0.1428* (10.23)	-0.0823* (8.24)	-0.0289* (3.95)	-0.0107* (2.19)	-0.0054 (1.22)

Note: The t-values for the test statistics are presented in parentheses and asterisks denote significance at the 5% level.
[a] rho_n is the nth order autocorrelation parameter where n is the number of days in the hedge period. hedge ratios, all hedging

Hedging Simulations

Hedging simulations were conducted to determine the mean returns from each hedge period for each exchange. These means were then regressed against the lagged means to correct for autocorrelation in the same way as the minimum risk hedge ratios were. For both exchanges none of the constants were significant after correcting for autocorrelation with the exception of the 65 day hedge period return for the Kansas City Board of Trade. These results suggest, in agreement with theory, that the expected returns to hedging are zero. In computing the transactions costs hedge ratios, returns were restricted to zero. After the transactions costs were subtracted, the returns to hedging were actually negative. This agains agrees with theory which states that people must be payed to assume risk. The 65 day hedge returns were also restricted to zero because the result seems to be an abberation from the rest of the hedge periods including the 65 day hedge period for Chicago. The complete results for Kansas City and Chicago are presented in appendix tables 1 and 2 respectively.

Utility Maximizing Hedge Ratios

The hedge ratios estimated above correct for data problems such as autocorrelation and a GARCH(1,1) error term but they still assume no transactions costs. This leads to higher hedge ratios than what hedgers actually do in the real world. In order to correct for this, a mean variance utility function was used to allow for transactions costs. Because this function must have a risk aversion level, hedge ratios were computed under five different levels of risk aversion ranging from almost risk neutral to extremely risk averse. Another aspect of allowing transactions costs to influence the hedge ratios is that producers and commercial firms often have different costs. Small producers who use brokers to trade futures contracts must pay significantly higher commissions costs than commercial firms who may have their own in-house brokers, a seat on the exchange, or their own floor traders. Thompson, Eales, and Seibold state that off-floor traders commissions costs may be as high as \$80.00 per contract or 1.6¢ per bushel. Commercial firms, on the other hand, have trading costs significantly lower. This research assumes producer commissions costs to be \$80.00 per contract and commercial trading costs to be \$9.00 per contract. This difference in trading costs will make a difference in the hedge ratios between producers and commercial firms. Commercial firms should hedge more because it costs them less.

The other component of trading costs is liquidity costs or slippage. Thompson, Eales, and Seibold found there was a higher cost of trading with Kansas City verses Chicago. The smallest difference found was \$0.54 per contract and the largest was \$14.01 per contract. Below, hedge ratios are computed for producers and commercial firms under low liquidity cost and high liquidity cost conditions.

Producer Hedge Ratios

The utility maximizing hedge ratios for producers under low and high liquidity cost conditions are presented in tables 9 and 10 respectively. The results show that until producers approach the strongly risk averse level and a long hedge period, they will not even hedge. Also, the hedge ratios are significantly lower than the ratios

Table 9. Utility Maximizing Low Liquidity Cost Hedge Ratios for Producers with Five Levels of Risk Aversion

	Risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8858	0.6681
5 day	0.0	0.0	0.0	0.0	0.0	0.0	0.7445	0.5722	0.9906	0.7656
10 day	0.0	0.0	0.0	0.0	0.0	0.0	0.8774	0.6664	1.0017	0.7682
21 day	0.0	0.0	0.0	0.0	0.3700	0.2098	0.9372	0.7262	0.9939	0.7778
65 day	0.0	0.0	0.0	0.0	0.8460	0.7322	1.0188	0.9114	1.0361	0.9293
130 day	0.0	0.0	0.2444	0.1063	1.0032	0.9285	1.0791	1.0108	1.0867	1.0190

Note: Trading costs are equal to commissions (1.6¢/bu.) plus liquidity costs (0.26308¢/bu. for Kansas City and 0.25232¢/bu. for Chicago).

Table 10. Utility Maximizing High Liquidity Cost Hedge Ratios for Producers with Five Levels of Risk Aversion

	Risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8669	0.6676
5 day	0.0	0.0	0.0	0.0	0.0	0.0	0.7035	0.5712	0.9866	0.7655
10 day	0.0	0.0	0.0	0.0	0.0	0.0	0.8567	0.6659	0.9996	0.7681
21 day	0.0	0.0	0.0	0.0	0.2757	0.2069	0.9277	0.7259	0.9930	0.7778
65 day	0.0	0.0	0.0	0.0	0.8137	0.7312	1.0159	0.9113	1.0358	0.9293
130 day	0.0	0.0	0.1182	0.1018	0.9906	0.9281	1.0778	1.0107	1.0865	1.0190

Note: Trading costs are equal to commissions (1.6¢/bu.) plus liquidity costs (0.54189¢/bu. for Kansas City and 0.26164¢/bu. for Chicago).

which assume zero transactions costs. As the risk aversion level approaches infinity (constant absolute risk aversion), the hedge ratios converge to the no transactions costs ratios. Notice also that the hedge ratios for producers under low liquidity costs are higher than when under high liquidity costs. This is consistent with theory in that as the costs decrease, marginal utility peaks at a higher use of hedging.

Commercial Hedge Ratios

Results of the utility maximizing hedge ratios for commercial firms are presented in tables 11 and 12. Commercial hedge ratios are larger than for producers because their commissions costs are much less. There is not as big a gap between the risk minimizing hedge ratios and these for commercial firms because their hedging costs are so low. The results show that the ratios have almost converged with the minimum risk ratios at the 0.1 risk aversion level compared to producers who still do not even hedge at this level for a one day hedge period. Also, because commercial firms' commissions costs are so much lower than for producers, the liquidity cost difference between Kansas City and Chicago makes a larger difference in the hedge ratios when compared to producers.

Utility Function Values

The final step in determining if and when hedgers should use the Kansas City or Chicago Boards of Trade to hedge is to compute the utility associated with hedging on each exchange. Using the utility maximizing hedge ratios for producers and commercial firms under both low and high liquidity costs, utility is calculated

Table 11. Utility Maximizing Low Liquidity Cost Hedge Ratios for Commercial Firms with Five Levels of Risk Aversion

	Risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	0.0	0.0	0.0	0.0	0.0	0.0	0.7120	0.5406	0.9818	0.7413
5 day	0.0	0.0	0.0	0.0	0.3675	0.2857	0.9529	0.7369	1.0115	0.7821
10 day	0.0	0.0	0.0	0.0	0.6870	0.5156	0.9826	0.7531	1.0122	0.7769
21 day	0.0	0.0	0.0	0.0	0.8503	0.6496	0.9852	0.7702	0.9987	0.7822
65 day	0.0	0.0	0.5814	0.4667	0.9923	0.8848	1.0334	0.9266	1.0375	0.9308
130 day	0.0	0.0	0.8870	0.8067	1.0674	0.9986	1.0855	1.0178	1.0873	1.0197

Note: Trading costs are equal to commissions (0.18¢/bu.) plus liquidity costs (0.26308¢/bu. for Kansas City and 0.25232¢/bu. for Chicago).

Table 12. Utility Maximizing High Liquidity Cost Hedge Ratios for Commercial Firms with Five Levels of Risk Aversion

	Risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	0.0	0.0	0.0	0.0	0.0	0.0	0.5234	0.5358	0.9630	0.7408
5 day	0.0	0.0	0.0	0.0	0.0	0.2749	0.9120	0.7359	1.0074	0.7819
10 day	0.0	0.0	0.0	0.0	0.4802	0.5099	0.9620	0.7525	1.0101	0.7768
21 day	0.0	0.0	0.0	0.0	0.7560	0.6468	0.9758	0.7699	0.9978	0.7822
65 day	0.0	0.0	0.2941	0.4567	0.9636	0.8838	1.0306	0.9265	1.0373	0.9308
130 day	0.0	0.0	0.7608	0.8021	1.0548	0.9981	1.0842	1.0177	1.0872	1.0197

Note: Trading costs are equal to commissions (0.18¢/bu.) plus liquidity costs (0.54189¢/bu. for Kansas City and 0.26164¢/bu. for Chicago).

under five different levels of risk aversion. The task then becomes to choosethe higher utility value between Kansas City and Chicago under the desired hedge period and risk aversion level. The differences in utility can then be computed and the break even liquidity cost difference calculated. This will give hedgers an idication of how significant or insignificant the differences in utilities are between Kansas City and Chicago.

Producer Utility Values

Utility maximization hedge ratios. The utility values for producers using hedge ratios that allow for transactions costs are presented in table 13. These results are under high liquidity costs. The results show that a producer would choose Kansas City under all levels of risk aversion and all hedge periods with only two exceptions. If using a 6 month hedge under a 0.001 risk aversion level or a one month hedge under a 0.01 risk aversion level, producers would choose Chicago because its utility value is greater. The utility value differences for the 6 month- and one month- hedges are 0.0074 and 0.0117 respectively. These differences are extremely small compared to the actual levels of utility which implies that neither Kansas City nor Chicago is a clear choice. Under low liquidity cost conditions where there is less of a difference between Kansas City and Chicago a producer would use Kansas City exclusively. The low liquidity cost results are presented in appendix table 3.

Risk minimizing hedge ratios. The results for the utility values for producers using risk minimizing hedge ratios are presented in table 14. These values show that

Table 13. Utility Function Values for Producers with Five Levels of Risk Aversion Hedging with Hedge Ratios Allowing for Transaction Costs and Under High Liquidity Cost Conditions.

	risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	-0.0009	-0.0009	-0.0094	-0.0094	-0.0939	-0.0939	-0.9392	-0.9389	-3.8523*	-4.6368*
5 day	-0.0047	-0.0047	-0.0465	-0.0466	-0.4651	-0.4657	-2.8906*	-3.0750*	-12.3160*	-18.9538*
10 day	-0.0093	-0.0093	-0.0925	-0.0927	-0.9252	-0.9272	-4.2751*	-5.0755*	-24.8120*	-37.8745*
21 day	-0.0210	-0.0211	-0.2099	-0.2106	-1.9789*	-1.9672*	-8.0128*	-10.0962*	-61.4387*	-86.6033*
65 day	-0.0857	-0.0861	-0.8547	-0.8606	-4.5033*	-4.7730*	-25.3458*	-30.6583*	-231.6650*	-287.8522*
130 day	-0.1892	-0.1893	-1.8528*	-1.8454*	-6.1022*	-6.8558*	-39.3470*	-49.3446*	-370.8696*	-473.4714*

Note: Asterisks denote that producers would have hedged. Commissions are 1.6¢/bu. and liquidity costs are 0.54189¢/bu. for Kansas City and 0.26164¢/bu. for Chicago.

Table 14. Utility Function Values for Producers with Five Levels of Risk Aversion Hedging with Minimum Risk Hedge Ratios and Under High Liquidity Cost Conditions.

	risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	-2.1673	-1.4219	-2.1690	-1.4248	-2.1856	-1.4540	-2.3514	-1.7458	-4.0098*	-4.6641*
5 day	-2.1815	-1.4670	-2.1906	-1.4827	-2.2818	-1.6397	-3.1940*	-3.2095*	-12.3163*	-18.9074*
10 day	-2.1774	-1.4548	-2.1977	-1.4875	-2.4016	-1.8145	-4.4400*	-5.0849*	-24.8238*	-37.7887*
21 day	-2.1482	-1.4672	-2.2016	-1.5437	-2.7352*	-2.3083*	-8.0708*	-9.9541*	-61.4268*	-86.4129*
65 day	-2.2462	-1.7623	-2.4525	-2.0195	-4.5155*	-4.5921*	-25.1453*	-30.3090*	-231.4432*	-287.4861*
130 day	-2.3661	-1.9458	-2.6977*	-2.3699*	-6.0128*	-6.6111*	-39.1641*	-49.0230*	-370.6774*	-473.1422*

Note: Commissions are 1.6¢/bu. and liquidity costs are 0.54189¢/bu. for Kansas City and 0.226164¢/bu. for Chicago.

under conditions where a producer would hedge, using the wrong hedge ratio is costly only at lower risk aversion and longer hedge periods. Notice that the times a producer would choose Chicago is the same as under utility maximization hedgeratios. The low liquidity cost risk minimizing utility values are presented in appendix table 4.

Commercial Firms Utility Values

Utility maximization hedge ratios. The utility values for commercial firms hedging with hedge ratios that allow for transactions costs and under high liquidity costs are presented in table 15. Since commissions costs for commercial hedgers is much less than producers, commercial hedgers will use Chicago slightly more. Under conditions where commercial firms would hedge they would choose Kansas City on all but six instances. These instances and the actual differences in utility are listed below:

> Under risk aversion level 0.001 - 3 and 6 month hedge periods.
> Differences: 3 month = 0.1061; 6 month = 0.1487
>
> Under risk aversion level 0.010 - 1 week, 2 week, and 1 month hedge periods.
> Differences: 1 week = 0.0404; 2 week = 0.0971; 1 month = 0.0216
>
> Under risk aversion level 0.100 - 1 day hedge period.
> Difference: 1 day = 0.1117

The results under low liquidity costs conditions are presented in appendix table 5. Like the producer results, under low liquidity costs, commercial firms will use Kansas City exclusively. The differences are slightly larger for commercial firms but still small compared to the actual utility values. For the most part, Kansas City is still the better market.

Risk minimizing hedge ratios. The results for commercial firms hedging with risk minimizing hedge ratios are presented in table 16. Like the producer results, using the wrong hedge ratios does not become costly until under lower risk aversion. Notice that it is less costly for commercial firms because their costs are lower to begin with. Also, the decision between exchanges remains the same as under utility maximization hedge ratios. It is apparent that using the wrong hedge ratio, while not maximizing utility, will not cause an error in the decision of which exchange to use. The low liquidity cost risk minimizing utility values are presented in appendix table 6.

Table 15. Utility Function Values for Commercial Firms with Five Levels of Risk Aversion Hedging with Hedge Ratios Allowing for Transaction Costs and Under High Liquidity Cost Conditions.

	risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	-0.0009	-0.0009	-0.0094	-0.0094	-0.0939	-0.0939	-0.7376*	-0.6259*	-2.5546*	-3.5895*
5 day	-0.0047	-0.0047	-0.0465	-0.0466	-0.4651	-0.4247*	-1.7215*	-2.0963*	-10.8782*	-17.8044*
10 day	-0.0093	-0.0093	-0.0925	-0.0927	-0.7681*	-0.6710*	-2.9804*	-3.9949*	-23.3816*	-36.7041*
21 day	-0.0210	-0.0211	-0.2099	-0.2106	-1.2334*	-1.2118*	-6.6483*	-8.8849*	-60.0122*	-85.3464*
65 day	-0.0857	-0.0861	-0.7856*	-0.6795*	-3.0902*	-3.3456*	-23.7442*	-29.0728*	-230.0445*	-286.2509*
130 day	-0.1892	-0.1893	-1.1006*	-0.9519*	-4.5219*	-5.2364*	-37.6838*	-47.6526*	-369.1982*	-471.7722*

Note: Asterisks denote that commercial firms would have hedged. Commissions are 0.18¢/bu. and liquidity costs are 0.54189¢/bu. for Kansas City and 0.26164¢/bu. for Chicago.

Table 16. Utility Function Values for Commercial Firms with Five Levels of Risk Aversion Hedging with Minimum Risk Hedge Ratios and Under High Liquidity Cost Conditions.

	risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	-0.7306	-0.3376	-0.7323	-0.3405	-0.7488	-0.3697	-0.9147*	-0.6615*	-2.5731*	-3.5798*
5 day	-0.7359	-0.3493	-0.7450	-0.3650	-0.8326	-0.5220*	-1.7485*	-2.0918*	-10.8708*	-17.7897*
10 day	-0.7353	-0.3479	-0.7557	-0.3806	-0.9596*	-0.7076*	-2.9979*	-3.9780*	-23.3818*	-36.6818*
21 day	-0.7280	-0.3546	-0.7813	-0.4310	-1.3149*	-1.1956*	-6.6505*	-8.8415*	-60.0065*	-85.3003*
65 day	-0.7722	-0.4399	-0.9785*	-0.6970*	-3.0415*	-3.2688*	-23.6713*	-28.9865*	-229.9692*	-286.1637*
130 day	-0.8219	-0.4976	-1.1534*	-0.9217*	-4.4685*	-5.1629*	-37.6199*	-47.5748*	-369.1332*	-471.6939*

Note: Commissions are 0.18¢/bu. and liquidity costs are 0.54189¢/bu. for Kansas City and 0.226164¢/bu. for Chicago.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Introduction

This research set out to determine if and when hedgers should use the Chicago Board of Trade to hedge hard red winter wheat. The expectation was that hedgers would be better off hedging with Chicago because utility could be better maximized due to lower liquidity costs at Chicago. This would provide a new method of risk reduction for producers and commercial users of hard red winter wheat. Although this is not what was found, the researcher believes this study is still a valuable contribution to studies on hedging.

When to Hedge with Kansas City and Chicago

Producers

Utility Maximization Hedge Ratios. The results presented in chapter 4 indicate that under almost all circumstances a producer who hedges will maximize utility by choosing Kansas City. Small off floor hedgers' commissions costs of 1.6¢ per bushel are high enough as to render insignificant even the largest difference in liquidity cost of 0.28¢ per bushel found by Thompson between the two exchanges. The two times producers would choose Chicago is under a slightly risk averse level of 0.001 and a hedge period of 6 months and under a risk averse level of 0.01 and a hedge period of one month. This study shows that producers will actually prefer the cash market to a hedge unless very risk averse or when hedging over a period of one month or more. These results are for the highest liquidity cost difference found by Thompson. Under the low liquidity cost difference, producers would never choose Chicago when hedging. Also, for the type of hedging most producers do, the liquidity costs should be small because they use heavily traded contracts such as July.

Risk Minimizing Hedge Ratios. Producers who use risk minimizing hedge ratios will make the same exchange choice as those producers who use utility maximizing hedge ratios. Under slight and moderate risk aversion, it is costly to hedge using the risk minimizing ratios. As risk aversion approaches strongly risk averse the cost disappears. This is because as risk aversion approaches infinity (constant absolute risk aversion), the utility maximization and risk minimizing hedge ratios converge.

Commercial Firms

Utility Maximization Hedge Ratios. The results are almost the same for commercial sized hedgers as for producers. Table 13 indicates that commercial firms will use Chicago only under slight risk aversion or for short hedge periods. Commercial firms will use Chicago more because their commissions cost are much lower (0.18¢ per bushel) which makes the liquidity cost differences between the exchanges relatively more significant. As with producers, the results show that commercial firms have to be moderately to strongly risk averse before they will prefer a hedge over the cash market for short time horizons. For longer hedge periods (3 and 6 months) commercial firms must be slightly risk averse to prefer a hedge over the cash market.

Risk Minimizing Hedge Ratios. Commercial firms using risk minimizing hedge ratios will choose Chicago under the same scenarios as with utility maximizing hedge ratios. Also, it is less costly for commercial firms to use risk minimizing hedge ratios because their transactions costs are much smaller than producers which makes their utility maximizing ratios closer to the risk minimizing ratios. For commercial firms, risk minimizing and utility maximizing ratios converge rapidly as risk aversion increases.

Limitations of the Study

There are several factors ignored by this study which limit its applicability. First, the hedge ratios are computed assuming infinite divisibility. In the real world hedging can only be done in 5000 bushel increments on the Kansas City and Chicago Boards of Trade. The mini contracts which are 1000 bushel increments can be used, but the liquidity costs will likely be much higher in these markets due to lower volume. Liquidity costs could be larger for large orders, orders during the low volume early months of trading, orders executed using stops, or for a trader who trades like a large number of other traders (Brorsen 1989). Another weakness is that the data period stops at May 31, 1994. The markets have had large price swings during in 1995 and 1996 setting all time historical highs. This would likely have changed the results somewhat. This study ignores other strategies such as options and forward contracting. The risk aversion coefficients were chosen to represent extremes but may not be relevant to individuals.

The new farm bill which was signed by President Clinton in the first week of April, 1996, is significantly different from previous legislation. Target prices, deficiency payments, the Acreage Reduction Program, and mandatory crop insurance are eliminated. A market transition payment will replace deficiency payments which will decrease gradually over 7 years and then cease. Sanders and Dicks state that producers will have a greater need for risk management. Two effects of this structural change are likely to be increased trading volume and greater price volatility. Greater trading volume will likely result in an even smaller liquidity cost difference between Kansas City and Chicago. A smaller liquidity cost difference would make the conclusion that Kansas City is the superior market for hedging hard red winter wheat more robust. Assuming the correlations between cash and futures remain the same and volatility increases proportionally on each exchange, an increase in volatility would decrease utility from hedging with Chicago more than it would decrease utility from hedging with Kansas City.

Contributions

As any experienced researcher knows, sometimes the research results do not give the expected answers. For the most part this is the case with this research. It seems that Chicago is only used under very few circumstances. It is still important though because it gives a definitive answer. According to Friedman's positivistic philosophy this research is validated because it matches what is observed in the real world; hedgers do use Kansas City futures. This research provides good information for hedgers trying to decide which exchange better fulfills their needs. It also should provide a caution to those who use traditional 1:1 hedge ratios as these are probably too high due to the costs associated with hedging.

Another contribution provided by this research is the new application of methods used to correct for autocorrelation using dummy variables. This will help other researchers with overlapping time series data better handle the problems of autocorrelation and heteroskedasticity.

Overall this study provides new information on when and how Chicago can be used to hedge hard red winter wheat. Thompson, Eales, and Seibold conclude that commercial firms, such as millers, may prefer a hedge in Chicago over Kansas City. This study finds, however, that producers and commercial firms will rarely choose Chicago, and that the gains in utility from choosing Chicago are very small. The results of this study indicate that the liquidity costs differences between Kansas City and Chicago are small and that hedgers will better maximize utility by using Kansas City due to better price protection. Note that the high liquidity cost difference found by Thompson, Eales, and Seibold occurs in the September contract observed in February which is not likely to be relevant for hedgers. Therefore, hedgers of hard red winter wheat should continue to use the Kansas City contract under most conditions.

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APPENDIX

Appendix table 1. Nonlinear Regression of Hedge Returns Against Lagged Hedge Returns - Kansas City

Variable	1 Day Coefficient	5 Day Coefficient	10 Day Coefficient	21 Day Coefficient	65 Day Coefficient	130 Day Coefficient
R	0.0633	0.1003	0.1119	0.1181	0.2438*	0.1919
(Constant,	(1.53)	(1.66)	(1.76)	(1.59)	(2.32)	(1.68)
hedge returns)						
rho_1						
(1st order	-0.0026	0.8324*	0.9336*	0.9670*	0.9860*	0.9890*
autocorrelation)	(-0.12)	(59.50)	(92.79)	(144.40)	(203.77)	(210.43)
rho_n[a]						
(Nth order		-0.1163*	-0.0792*	-0.0269*	-0.0138*	-0.0066
autocorrelation)		(-8.38)	(-7.81)	(-3.96)	(-2.79)	(-1.36)

Note: The t-values for the test statistics are presented in parentheses and asterisks denote significance at the 5% level.
[a] rho_n is the nth order autocorrelation parameter where n is the number of days in the hedge period.

Appendix table 2. Nonlinear Regression of Hedge Returns Against Lagged Hedge Returns - Chicago

Variable	1 Day Coefficient	5 Day Coefficient	10 Day Coefficient	21 Day Coefficient	65 Day Coefficient	130 Day Coefficient
R	0.0265	0.0561	0.0636	0.0613	0.1887	0.1367
(Constant, hedge returns)	(0.48)	(0.76)	(0.79)	(0.70)	(1.62)	(1.04)
rho_1 (1st order	0.0233	0.8482*	0.9344*	0.9701*	0.9893*	0.9908*
autocorrelation)	(0.33)	(64.12)	(94.71)	(140.57)	(201.25)	(233.91)
rho_n[a] (Nth order		-0.1247*	-0.0809*	-0.0262*	-0.0134*	-0.0064
autocorrelation)		(-9.39)	(-8.25)	(-3.80)	(-2.70)	(-1.49)

Note: The t-values for the test statistics are presented in parentheses and asterisks denote significance at the 5% level.
[a] rho_n is the nth order autocorrelation parameter where n is the number of days in the hedge period.

Appendix table 3. Utility Function Values for Producers with Five Levels of Risk Aversion Hedging with Hedge Ratios Allowing for Transaction Costs and Under Low Liquidity Cost Conditions.

	Risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	-0.0009	-0.0009	-0.0094	-0.0094	-0.0939	-0.0939	-0.9392	-0.9389	-3.6082*	-4.6302*
5 day	-0.0047	-0.0047	-0.0465	-0.0466	-0.4651	-0.4657	-2.6844*	-3.0693*	-12.0360*	-18.9463*
10 day	-0.0093	-0.0093	-0.0925	-0.0927	-0.9252	-0.9272	-4.0327*	-5.0688*	-24.5323*	-37.8668*
21 day	-0.0210	-0.0211	-0.2099	-0.2106	-1.8863*	-1.9643*	-7.7503*	-10.0884*	-61.1591*	-86.5950*
65 day	-0.0857	-0.0861	-0.8547	-0.8606	-4.2422*	-4.7643*	-25.0330*	-30.6479*	-231.3470*	-287.8417*
130 day	-0.1892	-0.1893	-1.7771*	-1.8428*	-5.7991*	-6.8455*	-39.0211*	-49.3335*	-370.5415*	-473.4603*

Note: Asterisks denote that Producers would have hedged. Commissions are 1.6¢/bu. and liquidity costs are 0.26308¢/bu. for Kansas City and 0.25232¢/bu. for Chicago.

Appendix table 4. Utility Function Values for Producers with Five Levels of Risk Aversion Hedging with Minimum Risk Hedge Ratios and Under Low Liquidity Cost Conditions.

	Risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	-1.8852	-1.4148	-1.8869	-1.4177	-1.9035	-1.4469	-2.0693	-1.7378	-3.7277*	-4.6570*
5 day	-1.8976	-1.4596	-1.9068	-1.4753	-1.9980	-1.6323	-2.9102*	-3.2021*	-12.0325*	-18.9000*
10 day	-1.8942	-1.4475	-1.9146	-1.4802	-2.1184	-1.8073	-4.1568*	-5.0777*	-24.5406*	-37.7814*
21 day	-1.8694	-1.4599	-1.9227	-1.5364	-2.4563*	-2.3010*	-7.7919*	-9.9468*	-61.1479*	-86.4056*
65 day	-1.9568	-1.7536	-2.1631	-2.0108	-4.2261*	-4.5826*	-24.8559*	-30.3003*	-231.1538*	-287.4775*
130 day	-2.0629	-1.9363	-2.3944*	-2.3604*	-5.7096*	-6.6016*	-38.8609*	-49.0135*	-370.3742*	-473.1326*

Note: Commissions are 1.6¢/bu. and liquidity costs are 0.26308¢/bu. for Kansas City and 0.25232¢/bu. for Chicago.

Appendix table 5. Utility Function Values for Commercial Firms with Five Levels of Risk Aversion Hedging with Hedge Ratios Allowing for Transaction Costs and Under Low Liquidity Cost Conditions.

	Risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	-0.0009	-0.0009	-0.0094	-0.0094	-0.0939	-0.0939	-0.5657*	-0.6206*	-2.2838*	-3.5822*
5 day	-0.0047	-0.0047	-0.0465	-0.0466	-0.4152*	-0.4217*	-1.4571*	-2.0891*	-10.5924*	-17.7967*
10 day	-0.0093	-0.0093	-0.0925	-0.0927	-0.6047*	-0.6657*	-2.7086*	-3.9874*	-23.0990*	-36.6963*
21 day	-0.0210	-0.0211	-0.2099	-0.2106	-1.0069*	-1.2048*	-6.3724*	-8.8767*	-59.7314*	-85.3381*
65 day	-0.0857	-0.0861	-0.6344*	-0.6734*	-2.7884*	-3.3355*	-23.4237*	-29.0623*	-229.7261*	-286.2404*
130 day	-0.1892	-0.1893	-0.8457*	-0.9427*	-4.2009*	-5.2254*	-37.3562*	-47.6415*	-368.8699*	-471.7610*

Note: Asterisks denote that Commercial Firms would have hedged. Commissions are 0.18¢/bu. and liquidity costs are 0.26308¢/bu. for Kansas City and 0.25232¢/bu. for Chicago.

Appendix table 6. Utility Function Values for Commercial Firms with Five Levels of Risk Aversion Hedging with Minimum Risk Hedge Ratios and Under Low Liquidity Cost Conditions.

	Risk aversion levels									
	0.0001		0.001		0.01		0.1		1	
Hedge Period	KC	Ch	KC	Ch	KC	Ch	KC	Ch	KC	Ch
1 day	-0.4485	-0.3305	-0.4502	-0.3334	-0.4667	-0.3626	-0.6326*	-0.6544*	-2.2838*	-2.2910*
5 day	-0.4521	-0.3420	-0.4612	-0.3577	-0.5524*	-0.5147*	-1.4646*	-2.0845*	-10.5924*	-10.5869*
10 day	-0.4522	-0.3406	-0.4726	-0.3733	-0.6764*	-0.7004*	-2.7148*	-3.9708*	-23.0990*	-23.0986*
21 day	-0.4491	-0.3472	-0.5025	-0.4237	-1.0360*	-1.1883*	-6.3716*	-8.8342*	-59.7314*	-59.7276*
65 day	-0.4828	-0.4312	-0.6891*	-0.6884*	-2.7521*	-3.2601*	-23.3819*	-28.9779*	-229.7261*	-229.6798*
130 day	-0.5187	-0.4880	-0.8502*	-0.9122*	-4.1653*	-5.1534*	-37.3167*	-47.5653*	-368.8699*	-368.8300*

Note: Commissions are 0.18¢/bu. and liquidity costs are 0.26308¢/bu. for Kansas City and 0.25232¢/bu. for Chicago.

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