Robust Risk Management Strategies for U.S. Hard Red Winter Wheat Producers

by

Brian D. Adam and Kim Anderson

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Harvest-time marketing strategies are analyzed for hard red winter wheat producers. A total of 6,561 strategies are considered, including purchases and sales of put and call options and futures contracts, as well as cash market and storage activities. The focus of the analysis is to identify strategies that are "robust" to uncertain price expectations and imprecise specification of a producer's tolerance for risk. It is assumed that a wheat producer uses the harvest-time futures price as a predictor of November 30 futures price, but that there is no market-based predictor of basis. The analysis attempts to find strategies that are relatively insensitive to the amount basis changes from harvest to November 30.

The results indicate that a strategy of selling wheat at harvest is optimal for a wide range of basis expectations and risk preferences, and is within 2% of the optimum for an even wider range. In addition, strategies are available that are robust for a range of basis expectations that includes 80% of historical basis changes, although a sacrifice in certainty equivalent returns of up to 3.5% is required. The data suggest that a producer may be able to form more precise expectations of basis change. If so, simple strategies are available that are robust, but which require a potential sacrifice of only 2% of the maximum certainty equivalent possible.

Introduction

Grain producers face much price and income risk. Although a wide array of alternatives is available with which to manage such risk, including futures, options on futures, and government programs, the many choices further complicate an already difficult marketing decision. Whether implicitly or explicitly, producers choose strategies based on their expectation of future price, as well as their tolerance for risk. Many strategies, particularly those with high expected returns, are quite sensitive to a producer's assumptions about future prices and risk tolerance. If the producer's assumptions are incorrect, such a strategy may result in lower returns than if a strategy with lower expected return/expected risk had been chosen. Thus, optimal use of these alternative pricing strategies requires a large amount of a producer's time in monitoring markets and other information sources, reducing the amount of time the producer can devote to other aspects of the production enterprise.

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Research on livestock marketing strategies suggests, however, that several simple combinations of futures and options on futures may greatly reduce the negative consequences of incorrect assumptions, while substantially improving on returns from traditional marketing strategies (Adam, Garcia, and Hauser). Moreover, compared to strategies with high risk and return, these simple combinations are easy to use, and require only a small sacrifice in potential returns for greatly reduced risk. Strike prices of put and call options are strategically selected so that even though returns are substantially above those obtained with traditional strategies, these "robust" strategies are relatively insensitive to incorrect assumptions by the producer.

The results by Adam, Garcia, and Hauser apply to nonstorable commodities, such as livestock. Here, robust strategies are identified that can be used by producers of hard red winter wheat. Major differences between livestock and hard red winter wheat include storage activities and associated basis changes and participation in government programs.[1] Simulation procedures are used so that the results are insensitive to characteristics of a particular time period. Strategic combinations of cash, futures, and put and call options, and storage activities are identified that will provide favorable risk and return results even when a producer's information is limited. The model is designed so that recommended strategies require only a small time commitment from the producer, so that typical wheat producers can profitably use them without detracting from other production and management activities.

This study builds on previous analyses of grain marketing strategies by directly focusing on robust strategies -- measuring the attractiveness of marketing strategies under alternative price expectations and utility specifications. Several strategies are identified which provide reasonable risk-adjusted returns even when the producer's risk preferences and price expectations are not precisely identified.

Procedures

A one-period model is used to simulate a producer's choice of post-harvest pricing strategies for varying levels of risk and price expectations. The producer makes marketing decisions when the period begins on June 20, and holds any positions taken until the end of the period on November 30.[2] These dates are chosen because June 20 is the typical harvest date in Central Oklahoma and November has the highest average cash price of the year (Anderson and Adam).[3] This limits the possible combinations of strategies, but also reduces

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[1]The analysis by Adam, Garcia, and Hauser for a nonstorable commodity had assumed an expected basis of zero, and no opportunity for sale of the cash commodity until the final period of the model. Also, this analysis does not include participation in government programs; continuing research will incorporate the option-like characteristics of government programs (Tirupattur and Hauser).

[2]If June 20 is not a trading day, the next trading day is used. If November 30 is not a trading day, the next earlier trading day is used.

[3]This is true whether or not storage costs are considered, evaluated over the period June 20, 1974 through May 31, 1990.

the complexity of the strategies and the time and effort needed by the producer to maintain them.

Specifically, given an initial cash position and expectation at time 1 of time 2 cash and futures prices, the producer maximizes expected utility of income by taking positions in hard red winter wheat futures and options markets, and by using storage activities and selling in the cash market. Income (R) is represented as the sum of the activities conducted in futures, options, cash, and storage markets. In order to focus on specific strategies that are robust across alternate price and risk preference scenarios, only discrete strategies are considered (i.e., the producer may not buy or sell fractions of contracts).

The producer income equation can be written as

$$\begin{aligned} R = {} & [\beta h_1(1 + r) + (1 - \beta)(h_2 - sc\Delta t)] \\ & + \Sigma_j[p_{j2} - rp_{j1}]NP_j + \Sigma_i[c_{i2} - rc_{i1}]NC_i + [f_2 - f_1]NF \\ & - \Sigma_j(tc_{j2} + rtc_{j1})abs(NP_j) - \Sigma_i(tc_{i2} + rtc_{i1})abs(NC_i) - (rtf)abs(NF) \end{aligned} \tag{1}$$

where
R = income (\$/bu)
β = % of wheat sold at time t = 1
h_t = cash price received at time t, t = 1,2
p_{jt} = price of put option at *j* th strike price at time t, t=1, 2
c_{it} = price of call option at *i* th strike price at time t, t=1, 2
f_t = price of futures contract at time t, t=1, 2
r = risk-free rate of return + unity (r adjusts time 1 premium and commission values to time 2 terms)
sc = physical storage costs, \$/bu/day.
Δt = number of days wheat is stored
NP_j = number of put options purchased or sold at *j* th strike price
NC_i = number of call options purchased or sold at *i* th strike price
NF = number of futures contract purchased or sold
tc_{jt} = transaction cost for put option at the *j* th strike price at time t, t = 1, 2
tc_{it} = transaction cost for call option at the *i* th strike price at time t, t = 1, 2
tf = transaction cost for futures contracts
**Negative values of NP_j, NC_i, and NF indicate contract sales while positive values indicate purchases.

The problem that the producer faces can be stated as

$$\text{Max EU(R)} \tag{2}$$

w.r.t. NP_j, NC_i, NF, β
s.t. NP_j, NC_i, NF are integers

or

$$\text{(3)} \qquad Max \quad \int U(R)L'(R)dR$$

w.r.t. NP_j, NC_i, NF, β
s.t. NP_j, NC_i, NF are integers

where U(R) is the producer's utility function and L'(R) represents the producer's assessment of the probability density function of R. In order to keep the producer's decision-making process relatively simple, the following assumptions are made:

(1) the producer's marketing decision does not change between June 20 and November 30;
(2) the producer liquidates all marketing positions on November 30; and
(3) the option premiums at November 30 have no time value remaining.[4]

Also, it is assumed that storage losses are minimal, so there is no quantity risk.

Given these assumptions, equations (1) and (3) can be rewritten as

$$\begin{aligned} R = {} & [\beta h_1(1 + r) + (1 - \beta)(h_2 - sc\Delta t)] \\ \text{(4)} \quad & + \sum_j [MAX(xp_j - f_2, 0) - rp_{j1}]NP_j + \sum_i [MAX(f_2 - xc_i, 0) - rc_{i2}]NC_i + (f_2 - f_1)NF \\ & - \sum_j (tc_{j2} + rto_{j1})abs(NP_j) - \sum_i (tc_{i2} + rto_{i1})abs(NC_i) - (rtf)abs(NF) \end{aligned}$$

where
xp_j = jth strike price for put option
xc_i = ith strike price for call option

[4]No time value remains because, in order to minimize basis risk, the hedger places contracts expiring in the month immediately following sale of the cash commodity. Although a small amount of time value may remain several days before expiration, it is assumed to be negligible. The commission costs of using futures and options contracts are considered in evaluating marketing alternatives. Here, the commission cost for futures is \$80/contract per round turn, or \$.016/bu. For options, it is 5% of the premium on each purchase or sale (e.g., commission cost on an option with a premium of \$0.10/bu. would be one-half cent/bu. if the option were allowed to expire, and one cent/bu. if it were offset with another purchase or sale in the options market). The commission costs assumed are those that are commonly charged by a full-service broker to a producer who trades only one or a few contracts at a time. Since average commission costs typically decrease as the number of contracts traded increases, these costs may be higher than many producers would be required to pay. Also, because full-service quotes were used, discounts may be available. Thus, the commission costs assumed here may influence the optimal choice slightly in the direction of a cash-only marketing strategy.

$$\text{(5)} \qquad Max\ EU(R) = MAX \int_{Lf_2}^{Uf_2} \int_{Lh_2}^{Uh_2} U(R)L'(h_2,f_2)dh_2,df_2$$

where
LF_2 = lower bound of integration for futures price
UF_2 = upper bound of integration for futures price
Lh_2 = lower bound of integration for cash price
Uh_2 = upper bound of integration for cash price

Also, prices are assumed to follow a bivariate lognormal distribution.[5]

Since producer risk preferences (through the utility specification) and expectations of the mean and volatility of prices (through the price density function) determine strategy selection, the model is optimized over several different risk preference and price scenarios. The range of price scenarios is chosen to reflect the range of prices observed from 1974 - 1993. It is assumed that the harvest-time futures price for the December Kansas City Board of Trade (KCBT) wheat futures contract represents the best available forecast of the November 30 futures price for the December contract. This is assumed to be \$3.50/bu. Similarly, it is assumed that current options premiums provide the best forecast of time 2 volatility. This is set at an annualized value of 0.19, calculated using Black's model. This volatility is assumed to be the same for both cash and futures prices. Initial (harvest-time) cash price is assumed to be \$3.15, reflecting an average central Oklahoma basis of -\$0.35/bu. (cash under futures). The producer in the model is assumed to form expectations about change in the December futures contract basis from harvest until the last trading day in November. November 30 cash price mean is calculated as June 20 cash price plus the producer's expected basis change from June 20 to November 30. The data provide historical basis patterns; however, there is no market-based forecast of basis change. In the base scenario, expected basis change is set at \$0.20/bu., reflecting the (rounded) average basis change over the years 1974 - 1993.

Expected basis change is varied in other price scenarios to reflect basis patterns observed historically. In all cases, the correlation coefficient in the bivariate price density function is set at 0.98, reflecting the historical average correlation between cash and futures prices on November 30 of every year. Table 1 indicates that the average basis change from June 20 to November 30 between the central Oklahoma cash price and the December Kansas City Board of Trade (KCBT) wheat futures contract was \$0.216/bu. However, as shown in figure 1, a basis change of between \$0.05/bu. and \$0.15/bu. was most frequent. Sixty-five percent (12 out of 20 years) of basis changes were \$0.20/bu. or less, and 80% (16 out of 20) were \$0.40/bu. or less.

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[5] Although some research suggests that prices are not distributed lognormally, a lognormal distribution is assumed here for convenience.

Expected utility is represented here by a mean-variance specification, where EU = E(R) - (q/2)V(R). Although mean-variance is theoretically inappropriate when options are part of the choice set, Garcia, Adam, and Hauser have shown in a similar context that the error is inconsequential for the range of prices considered here. Values of the absolute risk aversion parameter q for a risk averse producer and a slightly risk averse producer are set at 0.05 and 0.017, respectively. These are the values used by Adam, Garcia, and Hauser for a hog producer maximizing expected utility in terms of \$/cwt., adjusting them to \$/bu. terms by multiplying by 100/60.[6]

With an initial cash position equal to the size of a futures or options contract, the producer generates income by simultaneously choosing positions in futures, call and put options, and June 20 or November 30 sales in the cash market. To make the simulation manageable, several assumptions are made about the producer's choice set. Three strike prices for puts and three for calls are considered: one at the money, one \$0.10 in the money, and one \$0.10 out of the money. The producer is permitted to buy or sell only one futures contract, as well as one put and one call at each strike price.[7] Also, the producer is permitted to sell none, half, or all of the initial cash position at harvest, and must sell the remainder on the last trading day of November. The number of strategies involving cash positions and integer multiples of contracts is given by $3^{i+j+1+1}$, where 3 is the number of instruments traded (i.e., futures, put, and call options), i is the number of call strikes, and j is the number of put strikes, with a futures contract and a choice of β (the proportion of the cash position sold at harvest) each adding an additional combination. This means that 6,561 marketing strategies (3^8) are permitted under each price scenario.

Robust Strategies

A focus of the study is to identify marketing strategies that are relatively insensitive to producers' risk preferences and price expectations. First, the optimal strategy for each scenario (each set of price expectations and level of risk preference) is identified. Then, for each scenario, strategies that provide an expected utility (risk-adjusted income) within a specified percent of that achieved by the optimal strategy are identified. For example, if the specified percent is 5%, strategies that achieve an expected utility at least 95% of the maximum expected utility possible for each scenario are identified; if the specified percent is 2%, strategies that achieve an expected utility at least 98% of the maximum are identified. Strategies that achieve this minimum level of expected utility for more price scenarios than other strategies do are termed "robust" strategies. Then, strategies are identified that are robust for both a risk averse and a slightly risk averse producer. These strategies achieve the minimum level of expected utility for a range of price scenarios for both risk aversion levels;

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[6] 100 lbs./cwt x 1 bu./60 lbs. = 100/60 bu/cwt. These values were compared with smaller values. Smaller values for the risk aversion parameter resulted in very little difference between optimal strategies selected by risk averse and slightly risk averse strategies.

[7] Within the range of prices examined here, these restrictions were not binding. Theoretically, since the options are assumed to be correctly priced, having both puts and calls is not necessary. However, the differences in commissions costs between options and futures may negate any redundancy.

they would be especially appropriate for a producer who has difficulty precisely specifying his or her preference for risk.

The percent by which expected utility of identified strategies is allowed to differ from the maximum possible expected utility is set at two different levels for this analysis. The larger the percent, the lower the minimum level of expected utility a strategy must attain, and the more likely it is that strategies will achieve expected utility at least as high as that minimum level for a wider range of price scenarios. One level is determined by adjusting it so that the most robust strategies achieve the minimum expected utility for a range of scenarios that includes expected basis changes between \$0.00/bu. and \$0.20/bu., a range including 65% of historical basis changes. A second level is determined by adjusting it so that the most robust strategies achieve the minimum level of expected utility for expected basis changes between \$0.00/bu. and \$0.40/bu., a range including 80% of observed changes.

Data

Data used are daily Kansas City Board of Trade closing wheat futures prices, daily Gulf cash price bids for hard red winter wheat, and corresponding rail freight rates paid by a central Oklahoma elevator for transporting wheat to Gulf ports. Central Oklahoma cash prices are calculated by subtracting freight rates from Gulf cash bids. Daily observations of variable costs paid for storage in commercial facilities are used to calculate physical costs of storage, and an annualized interest rate of 8% is used to adjust prices to November 30 terms, thus taking into account opportunity costs.

Results

The results indicate that several simple and often-used strategies are optimal over several price scenarios for both risk averse and slightly risk averse producers. In addition, several strategies achieve expected utility that is within a small percentage of the optimal expected utility for a range of price scenarios for both risk averse and slightly risk averse producers. For example, a strategy of selling wheat at harvest and taking no other positions is optimal for a range of price scenarios and, along with several other simple strategies, is robust for an even larger range of price scenarios. However, in order to select strategies that are robust for the full range of price scenarios considered here, a producer must be willing to sacrifice up to 3.5% of the maximum possible expected utility. Those strategies are somewhat more complicated.

The two percentage levels used to identify robust strategies are 2.0% (the level which identifies strategies robust for expected basis changes ranging from \$0.00/bu. to \$0.25/bu. and from \$0.15/bu. to \$0.40/bu.) and 3.5% (which identifies strategies robust for expected basis changes ranging from \$.00/bu. to \$0.40/bu.). The robust strategies for the percentage level of 2.0% are identified in tables 2 through 4, and for the percentage level of 3.5 % are identified in tables 5 through 7. Tables 2 and 5 identify: (1) optimal strategies by an index number; (2) the certainty equivalent return (expected value minus a risk premium) for each of the optimal strategies (Robison and Barry); and (3) robust strategies for a risk averse producer. Tables 3 and 6 identify the same items for a slightly risk averse producer. Tables 4 and 7 identify strategies that are robust for both a risk averse and slightly risk averse producer. In each of the tables, the robust strategies are identified by an index number, ranging from 1 to 6,561, the number of discrete strategies considered, as well as by a verbal description.

For both a Risk Averse and Slightly Risk Averse producer (tables 2,3,5, and 6), the optimal strategy for expected basis changes ranging from \$0.00/bu. and \$0.20/bu. is #5468, which is a strategy where $\beta = 1$ and no other positions are taken; this strategy is simply to sell wheat at harvest, and achieves a certainty equivalent return of \$3.27/bu. If a risk averse producer (table 2) expects basis to increase by an amount ranging from \$0.25/bu. to \$0.40/bu. (expects cash price to increase relative to futures price by \$0.25/bu. to \$0.40/bu. over the time period), the optimal strategy is #1337, storing wheat on June 20 and buying a put with a strike price of \$3.40/bu., and selling the wheat and either exercising (selling) the put or letting it expire on November 30. The optimal strategy for a slightly risk averse producer (table 3) who expects basis to increase by an amount ranging from \$0.25/bu. to \$0.40/bu. is #1094, storing the wheat on June 20 and selling it on November 30, with no other positions ($\beta = 0$).

Thus, for both risk averse and slightly risk averse producers, selling cash at harvest is the best strategy unless the producer expects basis to increase by more than \$0.20/bu. If a risk averse producer expects basis to increase by \$0.25/bu. or more, putting the wheat into storage and buying a put with a strike price of \$3.40 is the best strategy. This takes advantage of the expected increase in cash price, but hedges with a put option. A slightly risk averse producer expecting a similar basis increase would also put wheat into storage, but would take no other positions.

However, as tables 2 - 4 indicate, both risk averse and slightly risk averse producers can achieve expected utility within 2% of the maximum possible for a wider range of expected basis changes by selecting a robust strategy. For expected basis changes between \$0.00/bu. and \$0.25/bu., any one of three strategies: #5468 (selling wheat at harvest); #5469 (selling wheat at harvest and buying a 3.60 call); and #5711 (selling wheat at harvest and buying a 3.40 put), provides a return within 2% of the maximum. For expected basis changes between \$0.15/bu. and \$0.40/bu., any one of three other strategies provides a return within 2% of the maximum: #1094 (storing wheat at harvest and selling in November); #1175 (storing wheat at harvest and buying a 3.50 put, and liquidating both positions in November); and #1337 (same strategy as #1175 but buying a 3.40 put instead of a 3.50 put). The first three strategies reduce risk by selling at harvest for a certain price, while the other three strategies take advantage of the expected rise in wheat price relative to futures price by holding a long cash position.[8] It should be noted that strategies which involve selling wheat at harvest and taking positions in futures and options markets would not be considered hedges by the Internal Revenue Service.

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[8]The sets of robust strategies in tables 2 through 4 are incomplete sets; more strategies were identified that meet the criteria, but the strategies listed in the tables were selected as representative of the larger list.

In contrast, as tables 5 - 7 indicate, nearly all of the strategies that are robust for the entire range of expected basis changes considered (\$0.00/bu. to \$0.40/bu.) involve selling half of the cash position at harvest and half in November (β = 0.5) and taking at least one position in futures and options markets. For example, in table 7 , six robust strategies are identified. Strategy #3281 is a strategy in which the producer sells half of the wheat at harvest and half on November 30, with no other positions. Strategy #3525 adds to this the purchase of a put with a strike price of 3.40 and purchase of a call with a strike price of 3.60.

Taking the results together, producers can select strategies that are robust for expected changes ranging from \$0.00/bu. to \$0.40/bu. by sacrificing up to 3.5% of the maximum possible certainty equivalent return. However, if a producer can predict basis change with somewhat more certainty, strategies are available that are robust for expected basis changes ranging from \$0.00/bu. to \$0.25/bu. and from \$0.15/bu. to \$0.40/bu., but which require only 2% sacrifice in certainty equivalent. Moreover, these strategies are simple, including only the cash position and no more than one futures or option position.

The data in table 1 suggest that it may be possible for producers to have some success predicting basis on November 30, and thus basis change from June 20 to November 30. The standard deviation of basis on June 20 was 0.13, while it was only 0.08 for November 30 basis. This suggests that when harvest-time basis is small, the likelihood of a large basis increase is high, but when harvest-time basis is large, the likelihood of a large basis increase is small.

Summary and Conclusions

Assuming that a wheat producer uses the harvest-time futures price as a predictor of November 30 futures price, the results indicate that a strategy of selling wheat at harvest is optimal for a wide range of basis expectations, and is within 2% of the optimum for an even wider range. In addition, strategies are available that are robust for a range of basis expectations that includes 80% of historical basis changes, but a sacrifice in certainty equivalent returns of up to 3.5% is required. The data suggest that a producer may be able to form more precise expectations of basis change. If so, simple strategies (such as selling wheat at harvest) are available that are robust, but which require a potential sacrifice of only 2% of the maximum certainty equivalent possible.

An important factor omitted from this analysis is the impact of government programs on a producer's marketing strategy. Continuing research will incorporate into the model the option-like effect of government programs (Tirupattur and Hauser; Kang and Brorsen).

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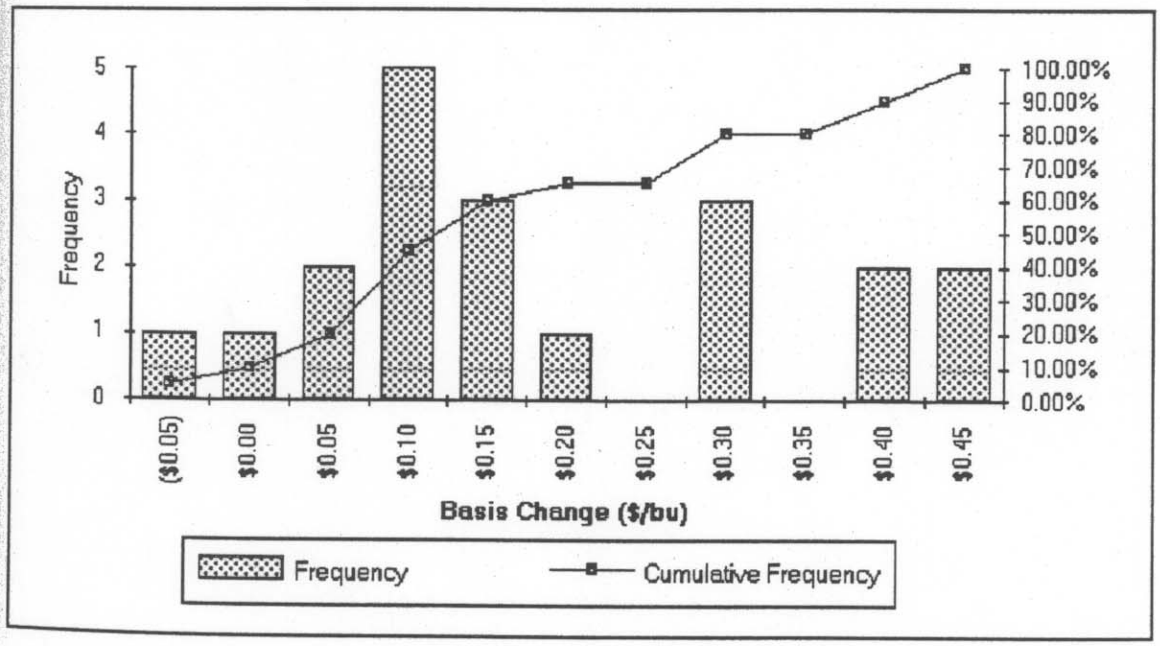

Figure 1. Frequency of Basis Changes from Harvest to November 30: 1974 - 1993.

Table 1. Daily (June 20 and November 30) Cash and KCBT Futures Prices, Bases, and Basis Changes, 1974 - 1993.

Date	December KCBT Futures Price ($/bu)	Gulf Cash Price ($/bu)	Basis: Central Oklahoma minus KCBT ($/bu)	Basis Change: November Basis minus June Basis ($/bu)
6/20/74	4.50	4.63	-0.42	
11/29/74	4.83	5.13	-0.25	0.17
6/20/75	3.44	3.63	-0.37	
11/28/75	3.56	3.85	-0.26	0.11
6/21/76	3.95	3.84	-0.66	
11/30/76	2.54	2.85	-0.25	0.42
6/20/77	2.55	2.60	-0.50	
11/30/77	2.72	3.11	-0.16	0.34
6/20/78	3.16	3.49	-0.23	
11/30/78	3.36	3.80	-0.11	0.12
6/20/79	4.49	4.65	-0.39	
11/30/79	4.39	4.98	0.03	0.43
6/20/80	4.39	4.32	-0.62	
11/28/80	4.88	5.32	-0.12	0.51
6/22/81	4.54	4.57	-0.52	
11/30/81	4.40	4.92	-0.03	0.49
6/21/82	3.84	4.19	-0.17	
11/30/82	3.79	4.31	-0.03	0.17
6/20/83	3.66	4.08	-0.12	
11/30/83	3.69	4.12	-0.11	0.01
6/20/84	3.84	4.08	-0.31	
11/30/84	3.68	4.13	-0.10	0.21
6/20/85	3.33	3.68	-0.20	
11/29/85	3.22	3.56	-0.21	-0.01
6/20/86	2.52	2.82	-0.25	
11/28/86	2.62	2.98	-0.19	0.06
6/22/87	2.70	2.96	-0.29	
11/30/87	3.01	3.35	-0.21	0.08
6/20/88	4.21	4.34	-0.42	
11/30/88	4.10	4.54	-0.11	0.32
6/20/89	4.27	4.60	-0.22	
11/30/89	4.13	4.58	-0.10	0.12
6/20/90	3.48	3.66	-0.36	
11/30/90	2.57	3.10	-0.02	0.34
6/28/91	2.89	3.23	-0.21	
11/29/91	3.69	4.13	-0.11	0.11
6/22/92	3.68	3.94	-0.28	
11/30/92	3.65	4.10	-0.10	0.18
6/21/93	2.99	3.25	-0.29	
11/30/93	3.76	4.15	-0.16	0.13
June Avg	3.62	3.83	-0.35	Average 0.216
June Std.Dev.	0.66	0.62	0.13	Std. Dev. 0.16
Nov Avg	3.63	4.05	-0.13	
Nov Std.Dev.	0.71	0.73	0.08	

Table 2. Robust Strategies for Risk Averse Producer: Strategies that Achieve Expected Utility within Maximum Minus 2.0 Percent

Exp. Futures Mean	3.50	3.50	3.50	3.50	**3.50**	3.50	3.50	3.50	3.50
Exp. Basis Change	0.00	0.05	0.10	0.15	**0.20**	0.25	0.30	0.35	0.40
Best Strategy	5468	5468	5468	5468	**5468**	1337	1337	1337	1337
Certainty Equ. ($/bu)	3.27	3.27	3.27	3.27	**3.27**	3.31	3.36	3.41	3.46
Robust Strategies (representative):									
4740 (β = 1; sell futures; buy 3.60 call)	X	X	X	X	X	X			
5225 (β = 1; sell 3.40 put)	X	X	X	X	X	X			
5468 (β = 1)	X	X	X	X	X	X			
5469 (β = 1; buy 3.60 call)	X	X	X	X	X	X			
5471 (β = 1; buy 3.50 call)	X	X	X	X	X	X			
5549 (β = 1; buy 3.50 put)	X	X	X	X	X	X			
5711 (β = 1; buy 3.40 put)	X	X	X	X	X	X			
6197 (β = 1; buy futures)	X	X	X	X	X	X			
6278 (β = 1; buy futures; buy 3.50 put)	X	X	X	X	X	X			
6440 (β = 1; buy futures; buy 3.40 put)	X	X	X	X	X	X			
1094 (β = 0);				X	X	X	X	X	X
1175 (β = 0; buy 3.50 put)				X	X	X	X	X	X
1337 (β = 0; buy 3.40 put)				X	X	X	X	X	X

Table 3. **Robust Strategies for Slightly Risk Averse Producer: Strategies that Achieve Expected Utility within Maximum Minus 2.0 Percent**

Exp. Futures Mean	3.50	3.50	3.50	3.50	**3.50**	3.50	3.50	3.50	3.50
Exp. Basis Change	0.00	0.05	0.10	0.15	**0.20**	0.25	0.30	0.35	0.40
Best Strategy	5468	5468	5468	5468	**5468**	1094	1094	1094	1094
Certainty Equ. ($/bu)	3.27	3.27	3.27	3.27	**3.27**	3.31	3.36	3.41	3.46
Robust Strategies (Representative):									
4740 ($\beta = 1$; sell futures; buy 3.60 call)									
5468 ($\beta = 1$)	X	X	X	X	X	X			
5549 ($\beta = 1$; buy 3.50 put)	X	X	X	X	X	X			
5711 ($\beta = 1$; buy 3.40 put)	X	X	X	X	X	X			
6197 ($\beta = 1$; buy futures; buy 3.50 put)	X	X	X	X	X	X			
6440 ($\beta = 1$; buy futures; buy 3.40 put)	X	X	X	X	X	X			
1094 ($\beta = 0$);				X	X	X	X	X	X
1175 ($\beta = 0$; buy 3.50 put)				X	X	X	X	X	X
1337 ($\beta = 0$; buy 3.40 put)				X	X	X	X	X	X
1418 ($\beta = 0$; buy 3.40 put; buy 3.50 put)				X	X	X	X	X	X

Table 4. Robust Strategies for Risk Averse and Slightly Risk Averse Producers: Strategies that Achieve Expected Utility within Maximum Minus 2.0 Percent

Exp. Futures Mean	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Exp. Basis Change	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
Robust Strategies (Representative):									
4740 (β = 1; sell futures; buy 3.40 put)	X	X	X	X	X	X			
5468 (β = 1)	X	X	X	X	X	X			
5549 (β = 1; buy 3.50 put)	X	X	X	X	X	X			
5711 (β = 1; buy 3.40 put)	X	X	X	X	X	X			
6197 (β = 1; buy futures)	X	X	X	X	X	X			
6440 (β = 1; buy futures; buy 3.40 put)	X	X	X	X	X	X			
1094 (β = 0);				X	X	X	X	X	X
1175 (β = 0; buy 3.50 put)				X	X	X	X	X	X
1337 (β = 0; buy 3.40 put)				X	X	X	X	X	X

Table 5. Robust Strategies for Risk Averse Producer: Strategies that Achieve Expected Utility within Maximum Minus 3.5 Percent

Exp. Futures Mean	3.50	3.50	3.50	3.50	**3.50**	3.50	3.50	3.50	3.50
Exp. Basis Change	0.00	0.05	0.10	0.15	**0.20**	0.25	0.30	0.35	0.40
Best Strategy	5468	5468	5468	5468	**5468**	1337	1337	1337	1337
Certainty Equ. ($/bu)	3.27	3.27	3.27	3.27	**3.27**	3.31	3.36	3.41	3.46
Robust Strategies:									
3281 ($\beta = 0.5$)	X	X	X	X	X	X	X	X	
3282 ($\beta = 0.5$; buy 3.60 call)	X	X	X	X	X	X	X	X	
3362 ($\beta = 0.5$; buy 3.50 put)	X	X	X	X	X	X	X	X	X
3524 ($\beta = 0.5$; buy 3.40 put)	X	X	X	X	X	X	X	X	X
3525 ($\beta = 0.5$; buy 3.40 put; buy 3.60 call)	X	X	X	X	X	X	X	X	X
3605 ($\beta = 0.5$; buy 3.40 put; buy 3.50 put)	X	X	X	X	X	X	X	X	X

Table 6. Robust Strategies for Slightly Risk Averse Producer: Strategies that Achieve Expected Utility within Maximum Minus 3.5 Percent

Exp. Futures Mean	3.50	3.50	3.50	3.50	**3.50**	3.50	3.50	3.50	3.50
Exp. Basis Change	0.00	0.05	0.10	0.15	**0.20**	0.25	0.30	0.35	0.40
Best Strategy	5468	5468	5468	5468	**5468**	1094	1094	1094	1094
Certainty Equ. ($/bu)	3.27	3.27	3.27	3.27	**3.27**	3.31	3.36	3.41	3.46
Robust Strategies:									
3281 ($\beta = 0.5$)	X	X	X	X	X	X	X	X	X
3282 ($\beta = 0.5$; buy 3.60 call)	X	X	X	X	X	X	X	X	X
3284 ($\beta = 0.5$; buy 3.50 call)									
3362 ($\beta = 0.5$; buy 3.50 put)	X	X	X	X	X	X	X	X	X
3363 ($\beta = 0.5$; buy 3.50 put; buy 3.60 call)									
3524 ($\beta = 0.5$; buy 3.40 put)	X	X	X	X	X	X	X	X	X
3525 ($\beta = 0.5$; buy 3.40 put; buy 3.60 call)	X	X	X	X	X	X	X	X	X
3527 ($\beta = 0.5$; buy 3.40 put; buy 3.50 call)									
3605 ($\beta = 0.5$; buy 3.40 put; buy 3.50 put)	X	X	X	X	X	X	X	X	X

Table 7. Robust Strategies for Risk Averse and Slightly Risk Averse Producers: Strategies that Achieve Expected Utility within Maximum Minus 3.5 Percent

Exp. Futures Mean	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Exp. Basis Change	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
Robust Strategies:									
3281 ($\beta = 0.5$)	X	X	X	X	X	X	X	X	X
3282 ($\beta = 0.5$; buy 3.60 call)	X	X	X	X	X	X	X	X	X
3362 ($\beta = 0.5$; buy 3.50 put)	X	X	X	X	X	X	X	X	X
3524 ($\beta = 0.5$; buy 3.40 put)	X	X	X	X	X	X	X	X	X
3525 ($\beta = 0.5$; buy 3.40 put; buy 3.60 call)	X	X	X	X	X	X	X	X	X
3605 ($\beta = 0.5$; buy 3.40 put; buy 3.50 put)	X	X	X	X	X	X	X	X	X