EFFECTS OF REDUCED GOVERNMENT DEFICIENCY PAYMENTS ON POST-HARVEST MARKETING STRATEGIES

By

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PREFACE

This study was conducted to determine the effects of current legislation on producers' choices of post-harvest marketing strategies and the resulting levels of risk and income. At the time most of the work was done, the 1996 farm bill had not been decided. Near the end of this study, Congress passed the "Federal Agricultural Improvement & Reform Act". However, work had already been completed on other farm program proposals, such as a reduced target price proposal. Although this particular proposal was not adopted, it was included in the results due to the information it contributed concerning market-based deficiency payments.

The results are not intended to provide marketing strategies for individual producers, but rather to determine the average effect of legislative changes on producers' income and the level of risk that they face. However, information concerning robustness of certain marketing strategies and general market behavior can be applied in the year-to-year choice of a marketing strategy.

Additionally, it should be noted that this study only looked at the intra-year effects of reducing or eliminating the deficiency payment program. It did not considered the effects of year-to-year variation in prices, and the associated risk in long-term investment decisions, of reducing or eliminating target prices.

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INTRODUCTION

Problem Statement

Government deficiency payments play an important role in determining marketing strategies for producers who maximize expected utility. The deficiency payment program is like a subsidized put option with costs coming mainly in the form of acreage reduction requirements and other compliance restrictions (Gardner; Irwin et al.).

Since price supports and hedging strategies serve similar purposes, optimal marketing strategies are influenced by the terms of the government programs. For example, Turvey and Baker found that for corn and soybean producers, participating in government programs decreases the use of futures and option contracts. The 1996 farm bill, entitled "Federal Agricultural Improvement & Reform Act" (FAIR), replaces the deficiency payment program with market transition payments. These payments are based on a specified amount of funds divided among the eligible acres signed into the program. They no longer depend on market prices and do not require set aside acres or planting restrictions (Sanders and Dicks).

What effect will the transition payments have on wheat producers' optimal, post-harvest marketing strategies? Specifically, two questions are of interest: First, deficiency payments are intended to help reduce revenue risk to producers; are marketing strategies available that can replace the risk-reducing features of deficiency payments? Second, if producers use those strategies, what will be the overall impact on revenue and risk? Once these questions are answered, policy makers can use the results to assess the amount by which producers may be able to offset any additional risk associated with the new legislation through the use of market-based strategies. Some have suggested that producers might be able to replace the risk-reduction features of the deficiency payment program with appropriate futures and options positions.

Commodity futures exchanges can use the results to determine how changes in farm programs might affect their trading volume. Conventional wisdom suggests that if the deficiency payment is reduced, use of futures and/or options will increase as producers attempt to manage the increased risk.

To answer these questions, prices resulting from the different farm program proposals must be estimated. Then, marketing strategies can be analyzed to predict the effect of the new payments on revenue and risk.

General Objective

Determine the effect of reducing or eliminating the government deficiency payments on post-harvest marketing strategies for winter wheat producers.

Specific Objectives

(1) Determine optimal marketing strategies under current and reduced deficiency payment scenarios and a no deficiency payment scenario for different levels of risk aversion.

(2) Determine the difference in risk adjusted returns of optimal strategies under the alternative policy scenarios.

Literature Review

The purpose of this review is to examine past research outlining different approaches to optimal marketing strategies, modeling the government deficiency payment program, and analyzing the effect of the deficiency payment program on marketing strategies.

Provisions of Marketing Strategies

Due to the uncertainty of prices, the changing nature of agricultural markets, and the availability of many different marketing tools, the choice of a marketing strategy is complicated. For example, storage, the government deficiency payment program, forward contracts, futures and options on futures can be used separately or in combination to form many strategies. Each of these marketing tools can help protect producers from unwanted price movements or allow them to take advantage of anticipated future price movements in the market. Although many of the marketing tools provide price protection, prevailing market conditions and individual risk preferences determine which strategy is best.

A hedged position in the futures market (which typically involves selling a futures contract expiring the month after the anticipated delivery) is one such strategy. It establishes on the sale date a price equal to the futures price plus the basis on the day the hedge is offset. Although the risk of decreasing prices is reduced, the ability to take advantage of increases in prices is forfeited. Problems associated with the use of futures contracts include: basis risk (unpredictable changes in basis over time), slippage (due to the constant movement of the market, reflected in the bid-ask spread), margin requirements, commission costs, and contract size and delivery dates that don't coincide with producers' crops[1].

Forward contracts are usually valued by a private purchaser according to an underlying price of a futures contract. Country elevators offering forward contracts typically cover purchases by making cash forward sales to processors or other merchants or by selling futures contracts (Barry, Hopkin, and Baker). The contract price includes some adjustment (either positive or negative) that takes into account the typical basis of an area at delivery. Producers who use forward contracts reduce the risk of a decline in price, but forfeit the gain from increases in price. Although it is similar to using a short futures position, a forward contract does not require margin money or brokerage fees. However, expected price may be lower since the provider of the contract will require a risk premium for bearing the risk (Brorsen, Coombs, and Anderson).

An option allows the purchaser the right but not the obligation to sell or buy the underlying instrument (i.e futures contract) at a stipulated price (strike price) for a specified period of time. However, a market-determined premium must be paid for this right, reducing the realized price.

If producers expect prices to increase, they can store the commodity to take advantage of the typically higher price occurring later. This strategy is perhaps the riskiest since storage is costly and prices can actually decline leaving producers vulnerable until they decide to sell the commodity.

Finally, participation in the government program allows producers to obtain a target price if cash prices are low without forfeiting the benefit of an increase in price. Costs of this program come mainly in the form of acreage reductions but other potential drawbacks include predetermined yields[2], restrictions on crop selection, changing program guidelines, and possible liquidity problems should a payback be required.

Development of Optimal Marketing Strategy Theory

Since theory attempts to explain the underlying principles of an observed phenomenon, a fair measure of accuracy would be how well it explains or predicts future behavior. Typically theories undergo revisions as time goes by and they are tested; current optimal hedging theory is no exception. Many of the present day models build on principles suggested by works such as Peck's. She suggested a portfolio approach to identifying optimal hedge ratios. She argued that hedgers consider both expected returns and risk in deciding how much of their cash position to cover with futures contracts. The resulting optimal hedge then is a tradeoff between the low risk-return resulting from a hedge and the higher risk-return resulting from not hedging. Thus, the decision of hedging is influenced by speculative motives as well as risk management objectives. This contrasted with early works suggesting there is a distinct difference between hedging and speculating (Keynes). Under this theory hedgers desire to transfer the risk of holding a position in the cash commodity to a speculator who is willing to take on the risk for a premium. Working later proposed that risk reduction or transfer was not the primary reason for hedging. Although he recognized the risk reduction possibility of hedging, he claimed that profits from arbitrage are the main reason for hedging.

Johnson later expounded on Working's theory by combining these differing views into a theory that explained both the risk-managing and the speculative motives of hedgers. A hedger who has already established a position in the cash market (e.g. has a crop growing or in storage) reduces risk by taking opposite positions in the futures market. The speculative component of the hedge occurs when expected price changes are taken into account. The optimal hedge ratio is determined by maximizing risk adjusted returns where risk is the standard deviation of returns.

Optimal Marketing Strategies

Several studies have calculated optimal hedge ratios under differing assumptions (Kahl; Lence, Sakong, and Hayes; Cecchetti, Cumby, and Figlewski; Bond and Thompson; Holthausen; Martinez and Zering; Brorsen).

Use of Historic Prices

One approach to this problem has been to identify strategies over previous years that would have provided consistently high returns. For example, Anderson and Adam noted that if perfect price forecasts were available so that producers sold at the highest price each year, they could have averaged $0.37 per bushel more than selling all wheat at harvest. Although this type of analysis provides information concerning the past, it is limited in application since the future is unknown and past occurrences do not necessarily reoccur. However, strategies identified that consistently performed well can provide insight into market response and behavior.

Maximizing Expected Returns

Another method used to select marketing strategies is maximizing expected returns. Anderson, Adam, and Sahs used a current futures price as the best forecast of the marketing date price. Based on this forecast, optimal marketing strategies were chosen that maximize returns. Maximizing expected returns is criticized because it values each dollar equally and may not weigh the possibilities of outcomes that are lower or higher than the expected outcome. Since future prices are not known, the variance associated with the expected price represents risk. These unanticipated changes in price represent the risk faced by producers and require the modification of profit maximization to account for the presence of risk.

Minimizing Risk

To incorporate risk into the optimal hedge, models have been constructed with the objective of minimizing risk. Since ending prices are not known and daily prices are variable, there is a variance associated with the price distribution. The optimal hedge ratio is then selected by minimizing the variance of returns. Mathews and Holthausen used this method while allowing for hedge adjustments to solve for the optimal hedge ratio. They found that a mean-variance approach works well in simple hedges (i.e. cross hedging is not considered) and that in most cases a fixed hedge ratio over the entire hedging period may be optimal. These results are also consistent with findings of Anderson and Danthine. This approach does not take into account expected returns and the differing opinions of individuals towards risk. Typically, more profitable opportunities are also more risky. Therefore, maximizing expected returns ignores the risk associated with those returns, and risk minimization (as measured by price deviations) ignores the expected returns.

Maximizing Expected Utility

Current optimal hedging models consider both profit maximization and risk aversion (e.g. Peck; Martinez and Zering; Adam, Garcia, and Hauser; Turvey and Baker; Lence, Sakong, and Hayes). Risk aversion refers to the need to be compensated for increasing levels of risk. The amount of the compensation required to make an individual indifferent between a risk-free investment (e.g., a U.S. government bond) and a risky investment is referred to as a risk premium.

Attitudes toward risk determine the amount of compensation needed by each investor. To account for typical attitudes toward risk, utility functions have been developed that exhibit properties unique to individuals with a specific attitude towards risk. The difference in these models is the effect of the level of wealth on the decision maker's attitude towards risk. Thus, by maximizing expected utility associated with different marketing strategies, expected return and risk are both considered, making the results more realistic.

Deficiency Payment Program

The deficiency payment is a farm program provided by the U.S. government that places a floor under the price that participating producers receive for a commodity. By establishing a target price, a payment is made to producers for the amount that the average U.S. monthly average price is below the target price. Thus, the deficiency payment program is like a subsidized put option, except that acreage may be restricted and yield predetermined (Gardner; Irwin et al.). For wheat, a producer must enroll in March to be eligible for the deficiency payment.

Currently, the United States Department of Agriculture (USDA) estimates the marketing year average price and makes an advance payment based on this prediction. A prediction is necessary since the marketing year average price is based on the monthly average prices occurring from June of the current year to May of the following year. One approach to predicting the deficiency payment has been to use the expected harvest price at the time of program sign-up (Anderson, Adam, and Sahs). The predicted deficiency payment is the difference between the target price and the expected harvest price. This method only considers the intrinsic value of the "option" and ignores the time value arising from the possibility that over the course of the marketing year U.S. prices will decrease, increasing the deficiency payment and making the "option" more valuable.

Kang and Brorsen and Tirupattur and Hauser use an average-option approach to value the deficiency payment. Since the deficiency payment is based on the difference between the target price and the marketing year average price (May 30 to June 1 of the following year), a pricing model is needed that considers the average price of the underlying asset over a period of time. The average option pricing approach considers both the intrinsic and time value of the option over a fixed period. Past research using the Black or Black-Scholes option pricing formulae only considered the time value between sign-up and harvest, ignoring the time value of the period from harvest to May of the following year. This time value can be critical especially when prices are near target levels. Kang and Brorsen suggested that an average option pricing model should also allow for non-normality and stochastic volatility since prices are neither normally distributed nor non-stochastic. However, they found only small differences between the payments predicted using a generalized autoregressive conditional heteroskedasticity (GARCH) average option pricing model and those predicted using a Black average option pricing model. In addition, daily prices were generated for the marketing year in their study while monthly prices will be generated in this study, making the effect of heteroskedasticity even less pronounced.

Effects of Government Programs on Optimal Marketing Strategies

Government farm programs provide producers with price support when market prices are low. These supports are like option contracts without margin requirements or maintenance and commissions costs. Since the price supporting effect of these programs can be recreated using private market tools, costs and effectiveness of the programs can be analyzed. For example, Ehrich stated, "The loan program has been directly competitive with futures markets as a mechanism for disposition of seasonal surpluses, since the loan, at predetermined prices, has been available as a hedge. Of fundamental importance to the operation of futures markets, then, has been the degree of use of the loan and, conversely, the amount of wheat available in private trade channels" (pg 314). Under the loan program, wheat produced on eligible acres could be placed under loan with the Commodity Credit Corporation (CCC). The producer received a predetermined rate at harvest and then later could either sell the wheat and pay the loan plus interest or let the CCC keep the wheat in which case producers were resolved of all responsibility. Not only did this program reduce hedging by producers, it also reduced export hedging activities since the government handled most of the production in low price years. Also, wheat for milling for export was made available at special prices out of the government CCC stocks, reducing the use of futures by millers (Ehrich).

The deficiency payment program is like a subsidized put option where the target price serves as the strike price of the option (Gardner; Irwin et al.). The government is the writer of the option and requires payment in the form of acreage reductions and other compliance restrictions. Although the deficiency payment and a put are similar, there are important differences. For example the required, yearly set aside acres (the primary cost of the government program) are determined by the previous year's ending stocks. (In recent years, stocks have been low, so the set aside requirement has been set at 0%, so that the cost of the government's "option" has come only in the form of compliance regulations). Advantages of the deficiency payment program include: advance payments that contain time value[3], no margin requirements or maintenance fees, reduced yield risk[4], no contract size specification[5], and no basis risk. Additionally, Heifner, Glauber, Miranda, Plato, and Wright note that through provisions of the deficiency payment program the average price received over a period of years can be increased. This is accomplished by government programs that reduce quantities reaching consumers or increase consumer demand (i.e. government food stamps or government export subsidies).

Although there are differences in the terms of the "options", they derive their intrinsic value in the same way (see figures 1 and 2). Government officials hoping to reduce farm program outlays have attempted to determine if established commodity markets could provide the benefits of this option with reduced government intervention[6]. Heifner, Glauber, Miranda, Plato, and Wright found that "Expanded use of futures and options markets by farmers can partly substitute for price support and deficiency payment programs in protecting farmer's incomes" (pg. v in the article summary). They suggest that although intra-year income can be stabilized by using futures, options, or cash

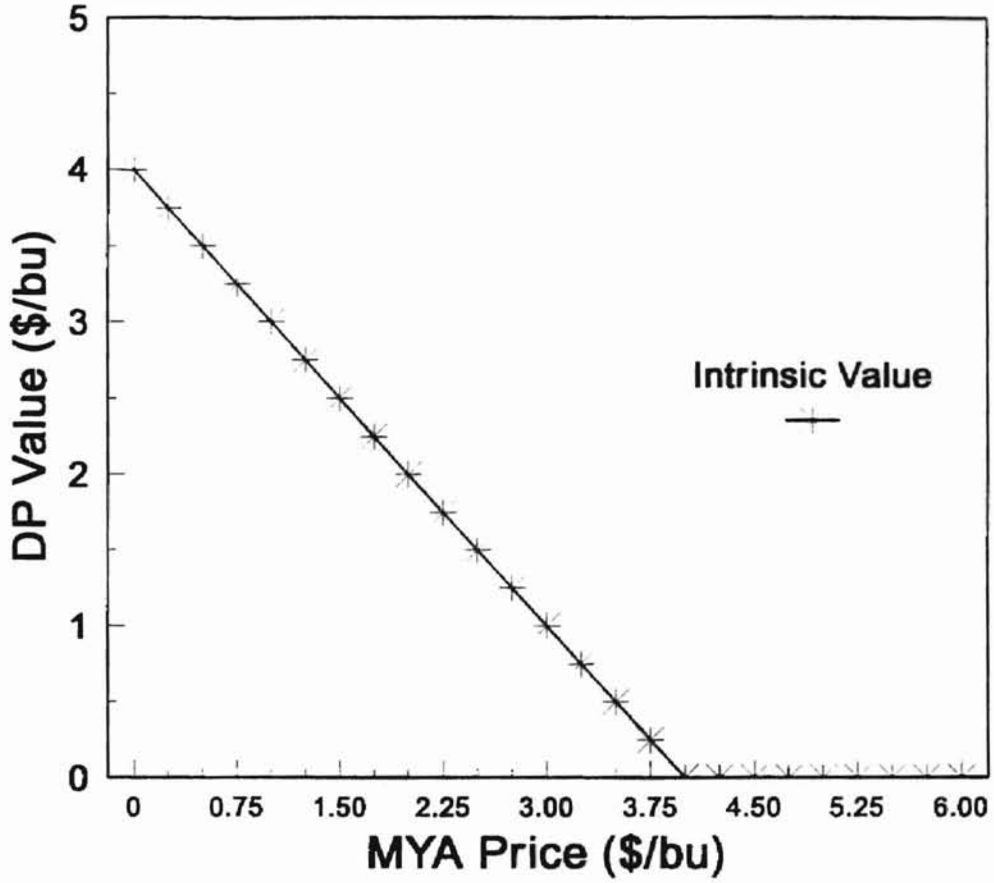

Figure 1. Deficiency Payment Value with Target Price = $4.00/bu.

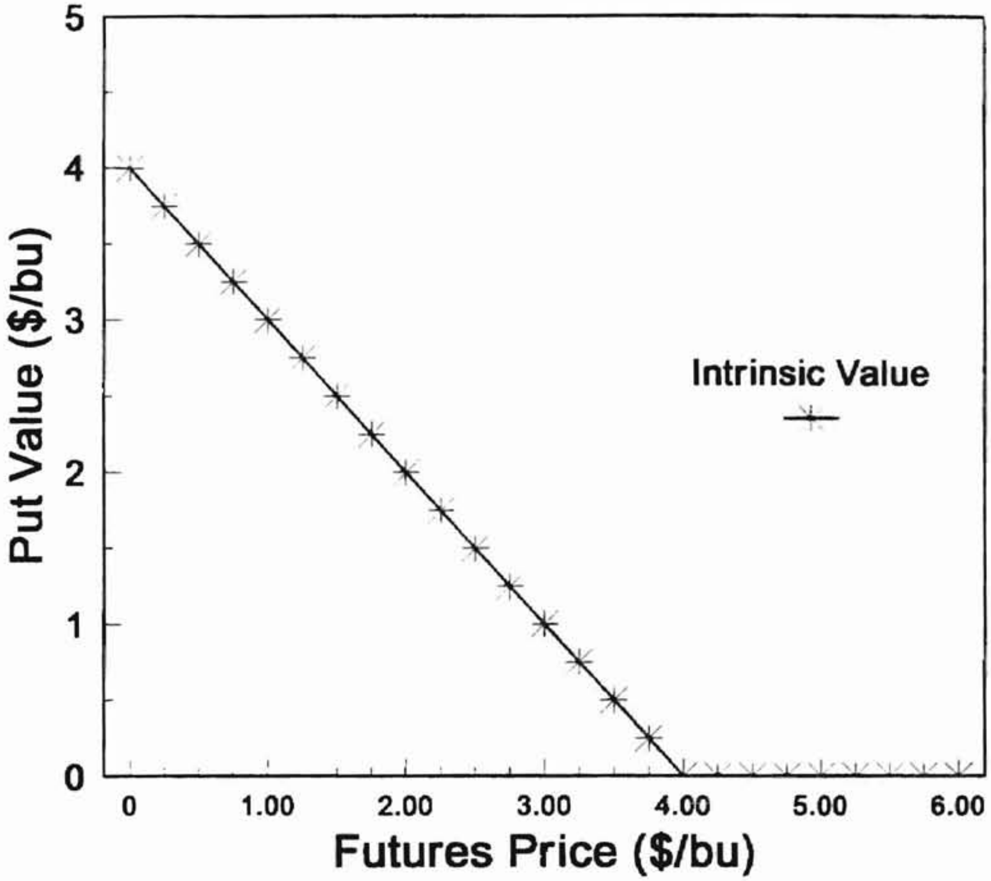

Figure 2. Put Option Value with a Strike Price of $4.00/bu.

forward contracts, inter-year income stability cannot be attained. This is because futures markets operate on a short-run horizon making inter-year stability difficult (Peck).

Since the deficiency payment and a put option serve similar purposes, optimal marketing strategies depend on government programs. Turvey and Baker considered the deficiency payment program and the loan program in their study analyzing marketing strategies for corn and soybean producers. They found that hedging decreased in the presence of the loan program for both corn and soybean producers, and that none of the expected corn production was hedged in the presence of the deficiency payment program. Volatilities of cash and futures prices were substantially higher under their "no government program" scenario suggesting that loan rates and target prices reduce price variability.

This study builds on previous studies by explicitly considering post-harvest marketing strategies for wheat producers of varying degrees of risk aversion. These strategies include the use of futures and options contracts with several strike prices to allow for more strategies. An example is a bull spread strategy that uses two calls with the same expiration date but with different exercise prices (Kolb). A call with an exercise price below the futures price is purchased while a call with an exercise price above the futures price is sold. This strategy anticipates an increase in prices but reduces risk of price declines by using calls. Another example is a bear spread strategy that uses two calls with the same characteristics as those described in the bull spread strategy, but the call with the lower exercise price is sold and the call with the higher exercise price is purchased. This strategy anticipates a decrease in futures prices but reduces the risk of an increase in prices by using calls.

Optimal strategies are found using integer solutions for number of futures and options contracts, and sensitivity analysis is performed on interest rates. Commission costs and maintenance fees are included in the model, and optimal strategies are selected by maximizing expected utility. Finally, the deficiency payment program is correctly modeled as an average option.

The above considerations make the model representative of the marketing decisions faced by wheat producers at harvest. By making the choices realistic (e.g. integer contract solutions, several strike prices for each contract, and availability of multiple contracts) the inter-relations of the various marketing tools can be studied as they relate to actual practices. Furthermore, the consideration of storage, purchase and sale of futures and options contracts, different risk aversion levels, and participation in the government program reveals the dynamic effect of changes in current government programs and other determining forces (e.g. changing interest rates or crop yield). Finally, by correctly modeling the deficiency payment program, results are more realistic (i.e. correctly modeling the time value of the deficiency payment and its effect on the optimal marketing strategy).

CHAPTER II

THE THEORETICAL MODEL

This section introduces a theoretical model for producer revenue from post-harvest marketing strategies, basing the model on those introduced by Wolf and by Adam, Garcia, and Hauser.

Wolf proposed a model of a hedger who maximizes expected utility by choosing simultaneous futures and options positions in an optimal hedge framework. Adam, Garcia, and Hauser modified Wolf's model to represent the marketing decision faced by livestock producers. Due to the additional marketing strategy alternatives considered here, modifications must be made. Thus, the model used is similar to the one Adam, Garcia, and Hauser used except it allows for storage and participation in the government deficiency payment program. Producer marketing revenue is represented by a one-period model that begins on June 20 (the typical harvest completion date in central Oklahoma) and ends on November 30 (the time of year with the highest average cash price; see figure 3). Producer revenue is calculated as:

Producer Revenue = Revenue from cash sale + Deficiency payment + Findley payment + Net revenue from futures/options transactions - Storage costs - Commission costs.

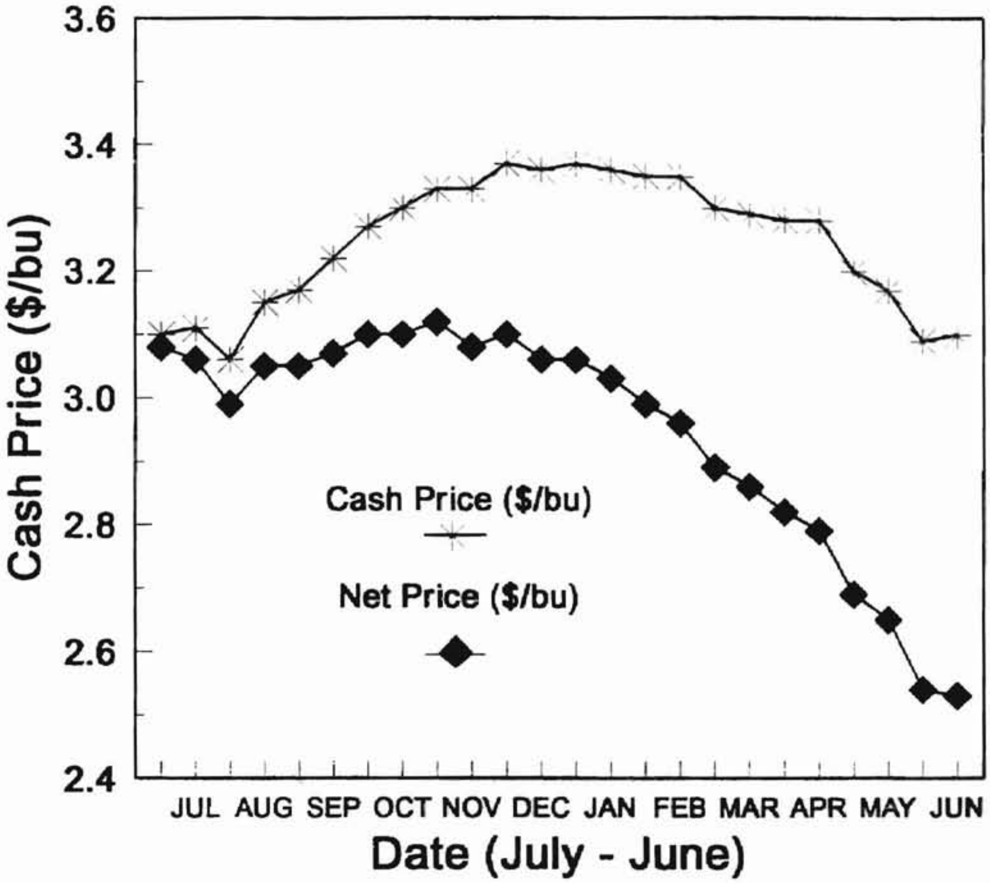

Figure 3. Average Price for Central Oklahoma Wheat Producers (1974-95). Storage Cost = .05¢/bu/mo.

Revenue is generated by buying or selling futures and options at harvest, selling wheat at harvest or storing until November 30 and then selling, and from government program payments, if the producer is participating in the program.

Producer revenue can be rewritten in equation form as:

$$
\begin{aligned}
(1) \quad R = {} & r\,((P_{c1}\,Y_p\,A_h)\beta) + (1-\beta)((P_{c2} - SC\Delta T)\,Y_p\,A_h) + G((DP_t + FP_t)Y_c A_{dp} + I_{dp}) \\
& + \Sigma_j[p_{j2} - r\,p_{j1}]NP_j + \Sigma_i[c_{i2} - r\,c_{i1}1]NC_i + [f_2 - f_1]NF - (r\,tc_o)\,abs(NP_j)abs(NC_i) \\
& - (r\,tc_f)abs(NF)
\end{aligned}
$$

where

R = revenue from marketing activities (in November 30 dollars),
P_{c1},P_{c2} = cash price received at time 1 and 2, respectively,
Y_p,Y_c = actual and program yield respectively,
β = percent of wheat sold at time 1,
A_h,A_{dp} = acres harvested and acres eligible for deficiency payments, respectively,
G = 1 if participating in government program; 0 otherwise,
DP_t,FP_t= total deficiency and Findley payments, respectively,
I_{dp} = interest earned on the March and December DP's ,
p_{jt} = put option premium at the jth strike price 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),
NP_j,NC_i, NF= number of puts, calls, and futures contracts (negative values indicate NF sales),
c_{it} = call option premium at the ith strike price at time t (t = 1, 2),
f_t = futures price at time t (t = 1, 2),
SC = storage costs per bushel,
tc_o,tc_f = transaction cost for an option (put or call) or futures contract (including initial margin requirements), and
ΔT = number of days grain is stored (163).

Since time 2 prices are not known, producers are assumed to maximize expected returns by using combinations of positions in the futures and option markets, selling on the cash market at harvest, storing in time 1 and selling in time 2, and participating in the deficiency payment program. These positions are based on expectations about ending price distributions given an initial cash position. The producer's problem is

(2)
$$\text{Max EU(R)}$$
$$\text{w.r.t. } \beta, NP_j, NC_i, NF$$
$$\text{s.t. } NP_j, NC_i, \text{ and NF are integers}$$

and

(3)
$$Max \int U(R)L'(R)dR$$
$$w.r.t.\ \beta,\ NP_j,\ NC_i\ NF$$
$$s.t.\ NP_j,\ NC_i,\ and\ NF\ are\ integers$$

where U(R) is the producer utility function and L'(R) represents the producer's assessment of the probability density function of R.

The producer is assumed to have an initial cash position equal to 10,000 bushels of wheat. At time 1 the producer formulates expectations of cash, futures, and options prices for time 2 and takes appropriate positions in the futures, and options markets. Also, part or all of the wheat may be sold in time 1. The producer's subjective expectations enter the model through the parameters of L'(R). At time 2 the producer offsets any futures or options positions taken in period 1 and sells any remaining grain at the prevailing Gulf price, less transportation costs to central Oklahoma.[7] It is assumed that the producer makes maintains futures and options positions taken in time 1 until November 30 when the period ends.[8] This limits the possible combinations of strategies but also reduces the time needed by the producer to maintain the strategies.

The following assumptions are made in solving the problem:

(a) producer harvests 10,000 bushels of wheat,

(b) marketing decisions are made on June 20,

(c) no storage losses (no quantity risk),

(d) all marketing positions are liquidated on November 30, with no time value remaining in options,

(e) futures and options markets are efficient,

(f) U. S. monthly average price returns are distributed lognormally,

(g) producer maximizes expected utility,

(h) three different risk aversion levels,

(i) deficiency payment assumptions:,
   1. acres harvested = acres eligible for payment (no set aside requirement, flex requirements are met with other acres, and no optional flex acres are used).
   2. actual yield = program yield.
   3. average historic marketing weights are used to calculate marketing year and 5-month average prices.

(j) monthly volatilities and means are calculated over years 1974-1993,

(k) time 1 prices are set at their average over crop years 1974-1993,

(l) producers may buy (sell) 1 or 2 of the following: futures contracts, puts at three different strike prices, and calls at three different strike prices. They can sell 0%, 50%, or 100% of their wheat at harvest or November 30. This results in 234,375 possible strategies,

(m) transportation from central Oklahoma to the Gulf port is $0.75/bu, and

(n) seasonal price and marketing patterns are the same with government programs as without them.

Given these assumptions, equations (2) and (3) can be rewritten as:

(4)
$$R = r\,((P_{c1}\ Y_p\ A_h)\beta) + (1 - \beta)(P_{c2} - SC\ \Delta T)\ Y_p\ A_h + G(DP_t + FP_t)Y_c\ A_{dp} + I_{dp}) + \Sigma_j [MAX(xp_j - f_2\ ,\ 0) - r\ p_{j1}]NP_j + \Sigma_i[MAX(f_2 - xc_i\ ,\ 0) - r\ c_{i2}]NC_i + (f_2 - f_1)NF - r\ tc_o\ abs(NP_j)abs(NC_i) - (r\ tc_f)abs(NF)$$

and

(5)
$$Max\,EU(R) = max\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{0}^{+\infty}\cdot\cdot\int_{0}^{+\infty} U(R)\ L'(P_{c2},F_2\,|\,US_N)\ S'(US_J\ \cdot\cdot\ US_M)dUS_J\cdot\cdot dUS_M,dP_{C2},dF_2$$

where

xp_j = jth strike price for put options,
xc_i = ith strike price for call options,
tc_2 = 0 if call option is not exercised,
P_{c2} = cash price at time 2,
F_2 = futures price at time 2,
US_N = U. S. monthly average price for November,
US_J = U. S. monthly average price for July,
US_M = U. S. monthly average price for May,
$L'(P_{c2}, F_2|US_N)$ = joint distribution of cash price and futures price conditional on the U.S. monthly average price for November, and
$S'(US_J \cdot \cdot US_M)$ = joint distribution of U. S. monthly average prices.

Equation 5 reveals that the cash and futures prices are conditional on the U. S. monthly average price for November. Specifically, a set of estimated coefficients and a generated error term are used to predict the Gulf and futures prices using the U. S. monthly average price for November. It also shows that the U. S. monthly average price for November is conditional on the all the previous monthly average prices. Starting in June, each succeeding U. S. monthly average price is conditional on all the previous generated U. S. monthly average prices. This is because the price generating equation uses the previous U. S. monthly average price along with the historical mean and volatility of the current month to predict the current monthly average price.

<u>Simulation Procedures</u>

Figure 4 on page 22 represents the simulation process used to solve the producer problem stated in equation 5. The price generator (figure 4, box #2) produces eleven, U.S. monthly average prices (June - May) using a randomly drawn error term, monthly means, and monthly volatilities.

Using the generated and initial U. S. monthly average prices, a marketing year and a 5-month average price is calculated (figure 4, box #5). These prices are used to

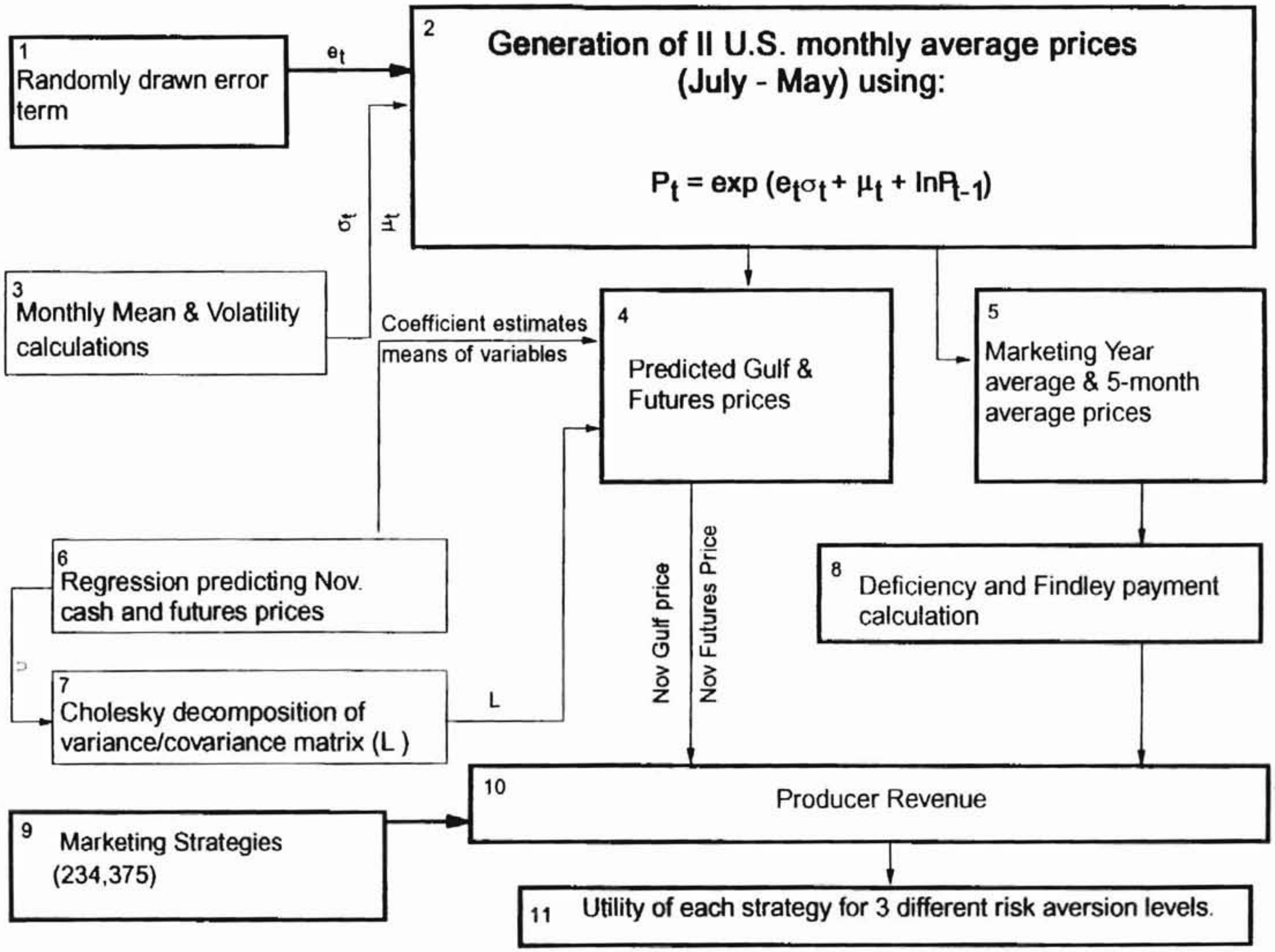

Figure 4. Simulation Process

calculate a deficiency and a Findley payment (figure 4, box #8) used in the producer revenue equation (figure 4, box #10).

Using the generated U.S. monthly average price for November, Gulf and futures prices on November 30 are predicted (figure 4, box #4). Specifically, estimated coefficient values (figure 4, box #6) and a generated error term are used to predict these prices. The generated error term is the product of two components. A Cholesky decomposition is performed on the regression variance/covariance matrix and serves as one component (figure 4, box #7). The other component is a randomly drawn error term (figure 4, box #4). The resulting prices determine the revenue from storage and futures/options transactions (figure 4, box #10).

Each marketing strategy (figure 4, box #9) is evaluated using the predicted prices and deficiency payments in the producer revenue equation (figure 4, box #10). These returns are adjusted for risk using both the mean-variance and the Cox-Rubinstein utility function (figure 4, box #11). One completion of this diagram produces one set of ending prices (11 U.S. monthly average prices, Gulf price and December Kansas City futures price on November 30, and the marketing year and 5-month average prices) used to calculated one possible producer return (R). The boxes in figure 4 not in bold type represent parameter estimates that do not change as the simulation is repeated. The portions of figure 4 in bold type are processes that change with each new draw of a random error term. The simulation process is repeated 2,000 times in order to solve the producer problem using Monte Carlo integration. The following sections provide a detailed explanation of the simulation summarized in figure 4.

Estimation Procedures

Monte Carlo integration is used to solve the producer's marketing decision represented in equation 5. It provides an estimate of the definite integral by randomly generating a large number of representative values for the variables. An estimate of the functional value is obtained by taking the simple average of these ending values. This approach is necessary since predictions of November 30 prices and U.S. monthly prices are needed on June 20 to evaluate the various marketing strategies.

This technique is numerically efficient, provides standard errors for the estimates and accommodates complex payoff structures. It can be illustrated using the following definite integral (Tirupattur and Hauser):

$$\overline{R} = \int_0^\infty R(y) f(y)\, dy. \tag{6}$$

An estimate of R can be obtained by drawing randomly a large number of sample values, y_i and calculating:

$$\hat{R} = \frac{1}{n} \sum_{i=1}^{n} R(y_i). \tag{7}$$

Specifically, an estimate of R (producer revenue associated with each marketing strategy) is obtained by generating a large number (2,000) of time 2 cash, futures, 5-month average, and marketing year average prices. These prices are then introduced into the producer revenue equation (4) to generate 2,000 revenues (R values) for each marketing strategy. Because these prices are predictions, the associated returns must be adjusted for risk.

Risk Adjustment

Since expected utility is a measure of well-being that adjusts uncertain returns for risk and attitude towards risk, some assumptions must be made when applying the results to real world conditions. As discussed in the literature review, different functional forms model response to risk differently.

The mean-variance (expected value-variance) approach has been a popular form due to its ease of interpretation and computational tractability. It is equivalent to expected utility maximization if profits are normally distributed or utility can be represented by a quadratic function. However, prices are not lognormally distributed (see Judge et al.,1980 p.299.) and inclusion of options in the model creates skewed distributions of returns. Also, a quadratic utility function implies that risk averseness increases as wealth increases, the opposite of what many people believe to actually exist.

Since there have been recent studies indicating the usefulness of mean-variance as an approximation of expected utility (Hanson and Ladd; Garcia, Adam, and Hauser), both the Cox-Rubinstein and mean variance utility functions are used. However, the Cox-Rubinstein does not require additional assumptions (such as normal distribution of returns) to satisfy expected utility axioms, making it more realistic (Robison and Barry). The mean variance can be written as:

(8) $$EU(R) = R - (q/2)v$$

and the Cox-Rubinstein can be written as:

(9) $$EU(R) = (1 \,/\, (1 - d))R^{1-d}$$

where q is the Arrow-Pratt coefficient of absolute risk aversion (AP), v is the variance of the return, q is the level of constant relative risk aversion, and R is the revenue figured in equation 4. The coefficient d is standardized to the AP coefficients of absolute risk aversion used in the mean-variance equation, by multiplying each AP coefficient by the amount of wealth from selling all the crop at harvest (e.g. $d = AP \times R^{*}$). Following procedures suggested by Raskin and Cochran, values for the AP coefficients are adapted from measures used by Adam, Garcia, and Hauser in order to adjust for different units of measurement. Specifically, three levels of risk aversion are considered: low risk aversion is assumed to be characterized by an Arrow-Pratt (AP) absolute risk aversion parameter of 0.000002; medium risk aversion, AP = 0.0001; high risk aversion, AP = 0.0003.

The Cox-Rubinstein function exhibits decreasing absolute risk aversion (DARA) which implies that initial levels of wealth affect risk aversion. Using this utility function, expected utility for each strategy is calculated by taking the average over the 2,000 possible prices of the utility of producer revenue (R) for each strategy.

Computational Method

A simulation process is used to generate 2,000 producer returns (R) for each of the marketing strategies. Gauss is the software chosen to complete this simulation, since it allows for integer solutions to nonlinear optimization problems (Aptech Systems, Inc.). Specifically, a grid-search technique is used to find the optimal integer solution (the strategy that maximizes expected utility) by replicating 2,000 different price paths and calculating producer revenue for each strategy at each of the 2,000 prices.

The price generation box in figure 4 represents the generation of U.S. monthly average prices from July of the current year through June of the following year (11 months). Assuming price returns are distributed lognormally,[9] a random sequence of U.S. monthly average prices is generated by drawing an error term from a standard normal distribution (figure 4 box #1) and introducing it into: (figure 4 box #2)

$$P_t = \exp\ (e_t \sigma_t + \mu_t + lnP_{t-1}) \tag{10}$$

where

P_t = U.S. monthly average price for month t (starting with July),
P_{t-1} = Previous U. S. monthly average price
e_t = random error term taken from standard normal distribution,
σ_t = volatility of log price returns of historical U.S. monthly average prices in month t, and
μ_t = means of the log price returns of historical U. S. average prices in month t.

This equation models the generation of prices as a random walk with a drift. Such a method suggests that the best estimate of tomorrow's price (P_t) is today's price(P_{t-1}) plus a random error term (e_t). A random walk is one in which future steps or directions cannot be predicted on the basis of past actions (Malkiel, pg. 24). Applying this to the futures markets, it means that short-run changes in price cannot be predicted.

U. S. monthly average prices are generated because they are used by the United States Department of Agriculture (USDA) to calculate deficiency payments. Since this price is an average of the six major classes of wheat, volatilities and means calculated from historic U.S. monthly average prices are used to generate U. S. monthly average prices instead of simulating cash prices for hard red winter wheat (one of the six major classes used to calculate the U.S. monthly average prices) and using them as an approximation for the U.S. monthly average prices.

The price generating process allows for seasonality of prices and stochastic volatilities by using average monthly means and volatilities to generate each U.S. monthly average price (e.g. the January historic mean and volatility is used to generate the January price etc.). Monthly means and volatilities of the price returns are based on historical values occurring from 1974 - 1993. The formulas used to calculate these values are:

(11) $$log\ price\ return = ln\left[\frac{Current\ US\ Monthly\ Average\ Price}{Previous\ US\ Monthly\ Average\ price}\right],$$

(12) $$\mu_t = \frac{\sum_{i=1}^{n} \ln\left(\frac{P_{it}}{P_{it-1}}\right)}{n},\ and$$

(13) $$\sigma_t = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left[\ln\left(\frac{p_{it}}{p_{it-1}}\right) - \mu_t\right]^2}$$

where
n = number of years in data minus one, due to the lag (19-1),
i = year (1974 - 93),
t = month (July - June)
μ_t = mean of the log price returns for month t , and
σ_t = volatility of returns for month t.

A scenario that considers the effect of no government deficiency payment on post-harvest marketing strategies requires an increase in volatility measures. Because a higher volatility causes the mean of a lognormal distribution to be higher (Cox and Rubinstein pg. 203-4), an adjustment is made to equation 10 following Arias; Naylor; et al.; and Mapp. It can be written as:

(14) $$P_t = exp\ (\ln P_{t-1} + e_t \sigma_t + \mu_t - \frac{1}{2} \ln[1 + \frac{P_{t-1}^2\ exp(\sigma^2) - 1}{P_{t-1}^2}]).$$

This equation allows for increased volatility without increasing the expected value. This is based on the idea that futures prices do not include a risk premium; therefore, as volatility increases the expected return should remain the same.

Using the generated U.S. monthly average prices, the marketing year average and 5-month average prices are calculated (figure 4, box #5). Each monthly average price is weighted according to the average amount of marketing that has historically occurred in that month. The marketing weights are based on 1977/78 to 1993/94 marketing year data and can be represented as:

(15) $$\frac{\textit{Expanded quantity purchased during the month}}{\textit{Expanded quantity purchased during the (n) months}}$$

where n = number of months incorporated into the average (USDA-NASS, 1974-1994). The average price (e.g. marketing year or 5-month) is calculated by summing the product of each monthly price and monthly weight over the appropriate number of months. For example, the marketing year average price can be figured as:

(16) $$MYA = \sum_{i=1}^{12} MP_i\ WT_i$$

where
MY = Marketing year average price,
MP_i = U.S. monthly price for month i (June through October), and
WT_i = Weight i (% of 12-month marketing that took place in month i).

These prices are used to calculate the deficiency and Findley payments (figure 4, box #8). The following section describes these calculations in detail.

Government Deficiency Payment Program

Wheat deficiency payments are designed to provide an economic "safety net" for producers who comply with acreage reduction requirements and other provisions of the annual wheat program. Deficiency payments are made directly to producers when the marketing year average prices received by farmers for all wheat are below specified target levels. The government deficiency payment (DP) is computed using current 1994-95 guidelines (USDA-ERS). The DP program uses average acres, yields, and prices to calculate the amount that participating producers are eligible to receive.

Acreage Calculations

The number of acres eligible for payment is figured from the crop acreage base allotted to each farm. It is the 5-year moving average of land planted to a crop plus land "considered planted" to a crop as established by an office of the USDA. "Considered planted" land includes acres that are put into an approved conserving use (ACR). These acres must protect the land from weeds, wind ,and water erosion. The percent of base acres required to be used for conservational purposes is determined by the stocks to use ratio. This ratio is a measure of the amount of wheat in storage relative to the amount used. If this ratio is high (i.e > 40%), set aside requirements (ACR) are increased to reduce the amount produced the following year. But if it is low, ACR requirements can be reduced to as low as 0%. The following formula is used as a guideline in determining ACR rates (USDA-ERS).

Stocks to Use Ratio	ACR Requirements
<= 40%	0% to 15%
> 40%	10% to 20%

Flex acres are established at 15% of the base acres and are intended to reduce the amount of government outlays while allowing farmers to have a greater "flexibility" in what they plant. This flexibility allows market forces to determine what crop is grown. Under the 1985 farm program, market forces (e.g. prices) had little effect on the quantity produced, since most productive acres are in the government program. To be eligible for the deficiency payment, acres must be planted to the crop they were signed in under. In addition, the '90 farm bill includes an optional flex acreage program which allows up to an additional 10% of the base acres to be planted to other crop(s) (USDA-ERS).

While ACR, flex, and optional flex acres are "considered planted" when figuring the base acreage of a farm, they are not included in the acres eligible for deficiency payment. The formula used to calculate acres eligible for the deficiency payment is

(17)
$$A_{dp} = A_b(1 - \alpha - \gamma - \lambda)$$

where
A_{dp} = acres eligible for deficiency payment,
A_b = base acres (acres planted to the program crop + those "considered planted",
α = percent required set aside acres,
γ = percent flex acres, and
λ = percent optional flex acres.

The formula used to calculate acres harvested is

$$A_h = \begin{cases} A_b(1 - \alpha - \gamma - \lambda) & \textit{If flex and/or optional flex acres are used for a crop other than wheat} \\ A_b(1 - \alpha) & \textit{otherwise.} \end{cases} \qquad (18)$$

Acres harvested and acres eligible for deficiency payment are different if flex or optional flex acres are planted to a crop other than wheat.

For example, consider a farm with a wheat base acreage of 100 acres, an ACR requirement of 7.5%, 15 flex acres used for soybeans, and an additional 10 optional flex acres of soybeans. The total acres harvested and eligible for deficiency payment are

$$\begin{aligned} A_h &= 100(1 - .075 - .15 - .10) \\ &= 100(1 - .675) \\ &= 67.5 \text{ acres} \end{aligned}$$

and

$$\begin{aligned} A_{dp} &= 100(1 - .075 -.15 - .10) \\ &= 100(.675) \\ &= 67.5 \text{ acres.} \end{aligned}$$

If the 15 flex acres are planted to wheat and the optional flex acres not used, the total acres harvested and eligible for deficiency payment are

$$\begin{aligned} A_h &= 100(1 - .075) \\ &= 100(92.5) \\ &= 92.5 \text{ acres} \end{aligned}$$

and

$$\begin{aligned} A_{dp} &= 100(1 - .075 - .15 - 0) \\ &= 100(.775) \\ &= 77.5 \text{ acres.} \end{aligned}$$

To get the number of bushels eligible for the deficiency payment, the program yield (official averages were frozen in 1985) is multiplied by the eligible acres. Similarly, number of bushels harvested is actual yield multiplied by harvested acres.

Price Calculations

The deficiency payment program uses a U.S. 5-month average price to calculate the December payment and a U.S. marketing year average price to calculate the July payment. These averages are based on monthly prices of the 5 major varieties of wheat (durum wheat, hard red spring wheat, hard red winter, soft red winter, and white).[10]

To obtain the monthly average prices, the National Agricultural Statistics Service (NASS) surveys the 21 major wheat producing states in the U.S. which account for 90% or more of the total wheat production. These surveys are sent to bonded grain purchasers in each state who have agreed to participate and have been informed on how to calculate data requirements.

Each state is divided into strata (areas of similar geographical size) with samples taken from each according to the total wheat capacity. For example, all the wheat purchasers in large-capacity strata might be surveyed while as few as one in five wheat purchasers in small-capacity strata might receive surveys. Surveyed participants are asked to report the total quantity of wheat purchased from farmers and the total dollars paid during a calendar month. Bushels purchased and dollars paid for each strata are summed up and multiplied by the reciprocal of the sampling fraction to get an expanded strata total. If one in five purchasers are surveyed, the results are multiplied by five to estimate the total for the entire strata. Expanded strata numbers are then summed to get a state quantity purchased and dollars paid. The state monthly average price is then figured by dividing expanded dollars paid by the expanded quantity purchased.

$$(19) \qquad \frac{\textit{expanded dollars paid for the entire month}}{\textit{expanded quantity purchased for the entire month}}$$

The U.S. monthly average price is figured by dividing the total expanded dollars paid for wheat in the 21 surveyed states by the total expanded number of bushels purchased for the 21 surveyed states. It can be figured as:

$$(20) \qquad \frac{\textit{expanded dollars paid for the U.S. for each month}}{\textit{expanded quantity sold for the U.S. for each month}}.$$

The 5-month average and marketing year average prices (respectively) are calculated using the same procedures:

$$(21) \qquad \frac{\textit{total U.S., survey-expanded dollars paid for wheat during 5 month period}}{\textit{total U.S., survey-expanded quantities purchased of wheat during 5 month period}}$$

and

$$(22) \qquad \frac{\textit{total U.S., survey-expanded dollars paid for wheat during 12 month period}}{\textit{total U.S., survey-expanded quantity purchased during 12 month period}}.$$

However, NASS does not publish data on either total quantities purchased or total dollars paid for wheat. Instead they publish monthly prices for each of the 12 months and each month's percent of total marketings (i.e. the quantity purchased) for both the 5 and 12 month periods. These weights are figured as follows:

$$(23) \qquad \frac{\textit{Expanded quantity purchased during the month}}{\textit{Expanded quantity purchased during the } (n) \textit{ months}}$$

where n = number of months incorporated into the average.

The average prices can then be calculated by summing the product of each monthly price and monthly weight. For example, the 5-month average price can be figured as:

(24) $$\sum_{i=1}^{5} MP_i \, WT_i$$

where
MP_i = U.S. monthly price for month i (June through October) and
WT_i = Weight i (% of 5-month marketings that took place in month i).

Loan Rates

A loan rate is the rate ($/bu) at which the government will provide a loan to farmers enabling them to hold their crops for sale at some later date. This loan allows producers to take advantage of increases in prices (reacquiring their crop by paying the amount of the loan plus storage costs) or protect against decreases in price (by forfeiting the grain and keeping the loan rate). It is effective for nine months and is nonrecourse, meaning the crop serves to pay back the loan even if current market price is less than the loan rate plus storage costs. Although the Secretary of Agriculture can adjust the basic loan rate according to stocks-to-use ratio (in order to maintain competitiveness), there are guidelines that establish the minimum and the estimate. The basic loan rate is based on a 5-year moving average (including the projected average of the current year) of marketing year average prices. This average excludes the highest and lowest prices of the five years and then is multiplied by 85 percent to arrive at the projected loan rate at the time of program sign-up. The minimum for the current year's loan rate is 95 percent of the previous year's rate after all adjustments are made. Table 1 summarizes the guidelines used to make adjustments to the basic loan rate using 1991 numbers as an example.

Deficiency Payment Rate Calculation

Producers participating in the government program have the opportunity to receive a

Table 1. Projecting Announced Loan Rate

Basic Loan Rate (projected)		$2.52/bu
Relevant Adjustment	Stocks-to-use ratio	
Adjust down 10%, if	above 30%	-.25/bu
Adjust down 5%, if	15 to 30%	n/a
Adjust down 0%, if	less than 15%	n/a
Adjusted Basic Loan Rate (ABLR)		$2.27/bu
If 80% of moving average (MA) is less than the minimum (MN), use ABLR (from above).	$2.37 (MA) $2.44 (MN)	$2.27/bu (ABLR)
If not, use higher of the minimum (MN) and ABLR (from above).		n/a
Additional adjustment to maintain competitiveness	up to 10%	$2.04/bu
Announced Loan Rate (projected)		$2.04/bu

deficiency payment at sign up in March. The March deficiency payment rate is calculated as:

(25) $$DP_{mar} = .5\ Max(TP - MYA_p,\ 0)$$

where
TP = Target price (established with passage of farm bill) and
MYA_p = Projected marketing year average price (determined by the USDA).

Since producers receive this payment in March, it can earn interest from March of the current year through July of the following year. This is because any advance payment received in March of the current year is not subject to repayment until July of the following year. Producers may have to pay back all or part of this advance payment if it exceeds the higher of the December or July deficiency payment calculation.

An additional deficiency payment calculation in December uses the U.S. 5-month average price plus \$0.10 to estimate the payment. Since the 5-month and marketing year average prices are weighted by the quantity sold, months with heavy marketings influence the average more than those with lighter marketings. Based on marketing weights from 77/78 to 93/94, on average 58% of the year's marketings occur in these five months. Thus, prices must decline substantially over the remaining seven months for the marketing year average price to be less than the 5-month average. By only paying 50% of the projected March calculation and adding \$0.10 to the 5-month average price, precautions are taken to reduce the chance of overpaying producers (which leads to a payback situation).

The December deficiency payment rate can be figured as: (USDA, pg. 2-43)

$$DP_{Dec} = Max(TP - Max(5\text{-}mo\ avg. + .10,\ BLR),\ 0). \tag{26}$$

Each time a payment calculation is made, all prior payments are subtracted (e.g. DP_{Mar} is subtracted from DP_{Dec}).

Findley payments or "emergency compensation" payments are made when the marketing year average price is below the basic loan rate. These payments are made to compensate producers for the loss of price support caused by the lowering of the loan rate from the basic loan level. In addition, it allows flexibility in setting the price "floor" in an attempt to allow market forces to determine price. This floor occurs when market prices fall below the basic loan rate causing producers to put grain in the loan program at the higher price. This program allows the wheat to stay on the market while producers receive a payment in the amount that the loan rate was adjusted. However, Findley payments have not been made for wheat since the 1987 program. The December Findley payment rate can be figured as: (USDA, pg. 2-43)

$$FP_{Dec} = Max\ .75(BLR - Max(ALR,\ MYA_p),\ 0). \tag{27}$$

Since the projected marketing year average price is used, only 75% of any positive amount is actually paid in December. Similar to the March payment, the December payment has the potential to earn interest from the time this payment is received (usually in January or February) through July of the following year.

The final deficiency payment rate calculation takes place in July of the following year using the actual marketing year average price. It can be calculated using: (USDA, pg. 2-44)

(28) $$DP_{Jul} = Max(TP - Max(MYA,\ BLR),\ 0).$$

However, program guidelines state that the deficiency payment in December is the guaranteed minimum payment. Stated another way, the producer receives the maximum of the December and the July deficiency payment.

The final Findley payment rate calculation also takes place in July when the marketing year average price is known. It is calculated as: (USDA, pg. 2-44)

(29) $$FP_{Jul} = Max(BLR - Max(ALR,\ MYA),\ 0).$$

A payback situation exists if the March deficiency payment is greater than the maximum of the December and the July payments ($DP_{Mar} > Max\ (DP_{Dec},\ DP_{Jul})$). This occurs in years when the projected marketing year average price is considerably different than the actual marketing year average price.

The same situation exists with the Findley payment; since the payment in December is based on the projected MY price, the final calculation in July could require a payback ($FP_{Jul} < FP_{Dec}$). The payback calculation can be summarized as: (Consolidated Farm Services Agency)

(29) $$PYBK = Max\ (DP_{Mar} - Max\ (DP_{Dec},\ DP_{Jul}),\ 0) + Max\ (FP_{Dec} - FP_{Jul},\ 0).$$

Total Payment Calculation

The total payment is made up of the deficiency payment and the Findley payment. The deficiency payment is the product of the eligible production (payment acres × program yield) and the deficiency payment rate (as discussed above). This payment is subject to a $50,000 limit for each person enrolled in the government program. The Findley payment is the product of the Findley payment rate (as discussed above) and the eligible production (payment acres × program yield); it is not subject to any maximum payment. Eligible production does not depend on actual yield but instead on the program yield (established on a county basis and periodically adjusted) or a proven yield (based on 5 years of past yields).

The total payment is figured as:

$$\textbf{(31)} \qquad \begin{matrix} Total \\ Payment \end{matrix} = Min\ (Max\ (DP_{Dec},\ DP_{Jul}) \times A_{DP} \times Y_P,\ \$50{,}000) + (FP_{Jul} \times A_{DP} \times Y_P).$$

Coefficient Estimation

Cash and futures prices at time 2 (November 30) are generated using coefficient estimates and a generated error term (figure 5, box #4). The coefficient estimates come from a regression that uses the generated U.S. monthly average price for November and other relevant variables to predict November 30 Gulf and futures prices (figure 5, box #6). The initial model used the following terms:

$$\textbf{(32)} \qquad \begin{bmatrix} GPN \\ DKCN \end{bmatrix} = \begin{bmatrix} f\ (USMON,\ USMOJ,\ GPJ) \\ f\ (USMON,\ GPJ,\ DKCJ) \end{bmatrix} + E$$

where
GPN = Gulf price on November 30,

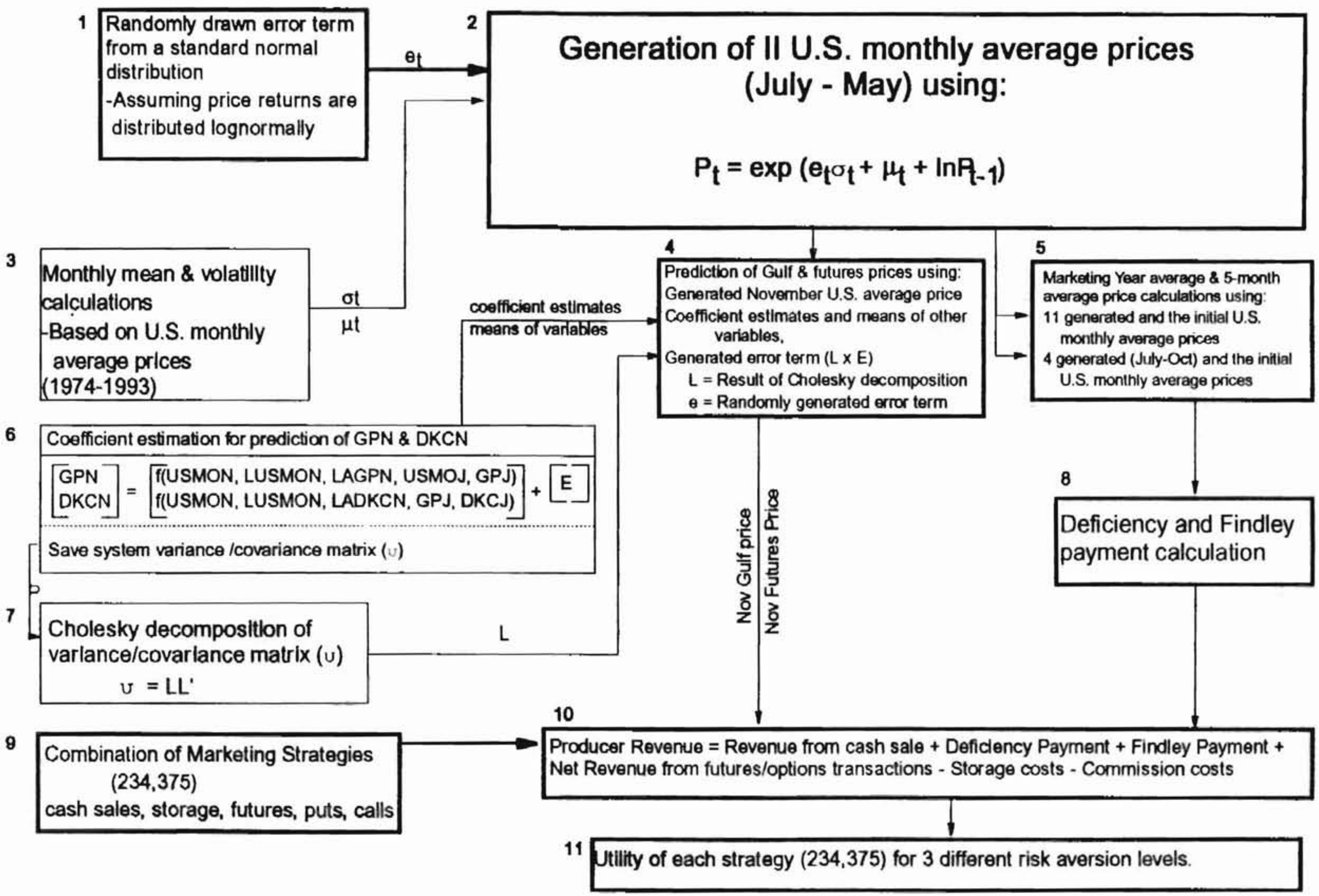

Figure 5. Detailed Simulation Process

DKCN	= price of the December Kansas City futures contract on November 30,
USMON	= the generated U. S. monthly average price for November,
USMOJ	= U.S. monthly average price for June,
GPJ	= Gulf price on June 20,
DKCJ	= price of the December Kansas City futures contract on June 20, and
E	= regression error term.

The June prices were included in both equations to capture the most current information relating the U.S. monthly average price to the Gulf price in the first equation and relating the U.S. monthly average price to the December Kansas City futures price in the second equation. Due to the presence of autocorrelation in the initial model, the lags of the Gulf price, U.S. monthly average price, and the December Kansas City futures price were added to the independent variables in the regression. This suggests that the appropriate model is a form of a partial adjustment model.

The regression results of the initial model indicated that the coefficients of USMON in both equations were not significantly different than 1 (p-value in the GPN equation = .585; p-value in the DKCN equation = .206). By restricting the coefficients on the USMON in each equation to equal 1 and subtracting them from the previous dependant variables, the Gulf and futures basis become the new dependent variables. Although not all of the independent variables are significant (see table 2), other regressions omitting nonsignificant variables led to significant variables becoming less significant. The final regression model can be expressed as:

$$(32)\quad \begin{bmatrix} GBASN \\ KCBASN \end{bmatrix} = \begin{bmatrix} .26618 - .32973\, LUSMON + .20771\, LAGPN - .12229\, USMOJ + .28786\, GPJ \\ -.10213 + .22391\, LUSMON - .12180\, LADKCN - .080841\, GPJ - .049737\, DKCJ \end{bmatrix} + E$$

Table 2. SUR Prediction of the Gulf/U.S. Monthly Average Price Basis and DKCBasis on November 30.

	Independent Variables								
Dep. Variable	LUSMON	LAGPN	LDKCN	USMOJ	DKCJ	GPJ	Intercept	Mean-Squared Error	Equation R^2
GBASN									
Unrestricted Coefficients	-.32976* (.1178)[a]	.20771 (.1052)	N/A	-.12229 (.1031)	N/A	.28786* (.1031)	.26618 (.2588)	.16456	.54
P-values of Coefficients	.013	.067	N/A	.225	N/A	.014			
KCBASN									
Unrestricted Coefficients	.22391 (.1451)	N/A	-.1218 (.13144)	N/A	-.08084 (.09878)	-.04973 (.0784)	-.10213 (.2295)	.02081	.37
P-values of Coefficients	.144	N/A	.379	N/A	.426	.535			

[a] Estimated standard errors of the coefficients are in parentheses.
* Indicate significance at the 5% level.
Note: The system of equations uses 20 Observations and has an $R^2 = .66$.

GBASN = Gulf price at time 2 (expiration of the December option) minus the U.S. monthly average price for November
LUSMON = Previous year's U.S. monthly average price for November
LAGPN = Previous year's average gulf price for November
USMOJ = U.S. monthly average price for June
GPJ = Gulf price on June 20
KCBASN = U.S. monthly average price for Nov. minus the Dec. Kansas City contract at time 2 (USMON-DKCN)
LDKCN = Previous year's December Kansas City futures contract at time 2
DKCJ = Price of the December Kansas City futures contract on June 20

where

GBASN	= November 30 Gulf price - U.S. monthly average price for November; (GPN = GBASN + USMON),
KCBASN	= U.S. monthly average price for November - November 30 price of the December Kansas City futures contract; (DKCN = USMON - KCBASN),
LUSMON	= previous year's U. S. monthly average price,
LAGPN	= previous year's Gulf price on November 30,
LADKCN	= previous year's average price of the December Kansas City futures contract for November, and
E	= regression error term.

The seemingly unrelated regression (SUR) approach in SHAZAM was used to estimate this system of equations. SUR provides more efficient coefficient estimates, since it allows the error structure from one equation to affect estimates of the related equation (futures and Gulf prices are related through a basis).

Generated Error Term

Since this system of equations is related through a typical basis, the simulation error term incorporates this information. Figure 5 is a detailed representation of the simulation described in the previous sections. An error term is generated as the product of two components (figure 5, box #4). To account for the relationship between cash and futures prices, a Cholesky decomposition is performed on the system variance/covariance matrix saved from the last iteration of the regression estimation (figure 5, box #6). The Cholesky decomposition of a matrix yields a matrix that if multiplied by the transpose of itself, yields the original matrix (figure 5, box #7). The result of this process serves as one component of the generated error term. It can be written as:

(34) $$\Omega = LL'$$

where

Ω = system variance/covariance matrix and
L = product of Cholesky decomposition

Using the variance /covariance matrix saved from the regression results, equation (34) can be rewritten as:

$$(35) \qquad \Omega = \begin{bmatrix} .1425140 & 0 \\ -.1183221 & .0400563 \end{bmatrix} \begin{bmatrix} .1425140 & -.1183221 \\ 0 & .0400563 \end{bmatrix}.$$

The other component of the generated error term is a 2x1 matrix of randomly generated error terms (using a standard normal distribution),

$$(36) \qquad \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}.$$

Combining these components, the generated error term for the prediction of the Gulf and futures prices can be represented as:

$$(37) \qquad \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} .1425140 & 0 \\ -.1183221 & .04005628 \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

where v_1 and v_2 are the simulation error term, the second matrix is the 2x2 product of the Cholesky decomposition of the system variance/covariance matrix, and e_1 and e_2 are randomly drawn error terms. The equation used for the prediction of the GPN and DKCN can be written as: (figure 5, box 4)

$$(38) \qquad \begin{bmatrix} GBASN \\ KCBASN \end{bmatrix} = \begin{bmatrix} .26618 - .32973\ LUSMON + .20771\ LAGPN - .12229\ USMOJ + .28786\ GPJ \\ -.10213 + .22391\ LUSMON - .12180\ LADKCN - .080841\ GPJ - .049737\ DKCJ \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

Strategy Evaluation

Using the calculated deficiency and Findley payments (figure 5, box #8) and the calculated November 30 prices (figure 5 box #4), the producer revenue (figure 5 box #10) can be calculated for each marketing strategy (figure 5, box #9). After one completion of the simulation (represented by figure 5), each strategy (consisting of different combinations of cash sales, storage, futures, puts, and calls) is evaluated at the generated prices. The resulting producer revenues (one for each strategy) are adjusted for three different levels of risk aversion (figure 5, box 11) using the both the mean-variance and the Cox-Rubinstein utility functions (equations 8 and 9). At the end of one simulation process, each strategy has three associated risk adjusted returns. The Monte Carlo integration evaluates each of the 234,375 strategies over 2,000 sets of prices producing a risk-adjusted return for each strategy for each risk aversion level.

Model Specification

The simulation is based on prices occurring over 1974 - 1993, except that the futures price is constrained to be unbiased (e.g. markets are assumed to be efficient). In other words, it is assumed that the June 20 December futures price is the best available predictor of the November 30 December futures price. This means that although on any given year the November 30 price could be higher or lower than the June 20 price, the average November 30 futures price is the same as the average June 20 price. Similarly, it is assumed that the options premiums on June 20 equal their expected value.[11]

Also, it is assumed that transaction costs are $80/contract for options and

$70/contract for futures, and that the margin requirement for futures contracts is $800 per contract. These prices are based on quotes from the following commodity brokers: Dean Witter Reynolds Inc., Merryl Lynch, Smyth Barney & Harris, and Cowless Sabol & Company Inc. Commission costs varied from $36 per round turn to $80 per round turn for futures contracts and from $36 per round turn to $90 per round turn for options contracts. Volume discounts do exist (one broker required 25 contracts for a discount) but exact amounts are offered only after the transactions have been made.

Most brokerages require an initial deposit of around $5,000 to open an account. After margin requirements are taken out of this deposit, the balance is typically deposited in a money market account that accrues interest. If margin calls are made, the account is deducted for the amount and if positions become more valuable, the account is credited. A U.S. treasury bill can also be deposited with the broker to cover potential margin calls; however, the customer's account is only credited with 90% of the face value. Also, the initial margin must be made in cash when pledging a T-bill. Initial margin requirements ranged from $650 to $1,200 for futures contracts. Options that are purchased do not require a margin requirement since the premium paid is the maximum amount that can be lost. Margin requirements for writing options were not available due to the many factors that determine them. However, as an approximation, the Federal Reserve has established the following minimums for writing a call option on stock.

(a) In-the-money calls: 100% of the proceeds from the sale of the option + 20% of the value of the underlying stock position(s),

(b) Out-of-the-money calls: 100% of the proceeds from the sale of the option + 20% of the value of the underlying stock position(s), or

(c) Out-of-the-money calls: 100% of the proceeds from the sale of the options + 10% of the value of the underlying stock position(s); whichever is less.

The producer is assumed to have harvested 10,000 bushels of wheat (equivalent to 333⅓ acres based on an average yield of 30 bu/acre). At harvest, the producer may buy (sell) one or two 5000-bushel futures contracts, and one or two 5000-bushel put and/or call contracts at each of three strike prices. The producer may sell all, one-half, or none of the crop at harvest, and any grain produced but not sold at harvest is sold on November 30 at the prevailing Gulf price less transportation costs of $0.75/bu.

For each strategy, expected utility is calculated, and for each level of risk aversion the strategy with highest expected utility is selected. Expected utility measures are converted into risk-adjusted dollars by expressing them as certainty equivalents. The certainty equivalent measure for the Cox-Rubinstein utility function is

(39) $$C.E. = [(1 - d) \cdot U]^{1/(1-d)}.$$

The certainty equivalents for the mean-variance utility function are equal to the utility calculations due to the form of the equation.

Thus, economic significance is used rather than statistical significance. The model is optimized for four scenarios, all of which set time 1 (harvest-time) Gulf cash, Kansas City futures, and U.S. monthly average prices at their average June 20 price over the last 20 years. Since harvest-time prices are set at historical averages, the model is not appropriate for recommending particular strategies in a particular year. Rather, the model is designed to assess the average effect that reducing or eliminating government deficiency payments might have on producers' marketing strategies.

In the first scenario, target price is set at its current level ($4.00/bu.). In a second scenario, the target price is reduced to the average of previous June monthly average U.S. prices, reflecting current farm policy proposals to reduce target prices.[12] Both of these assume the producer participates in the government deficiency payment program.

In the third and fourth scenarios it is assumed that no deficiency payment program exist. If the current program encourages producers to produce more than they otherwise would, resulting in higher stocks, price volatility is probably lower than it would be without a program. To allow for the possibility that prices would become more volatile without a government program, it is assumed in a third scenario that prices are 50 percent more volatile and in a fourth scenario that prices are 100 percent more volatile than under the current program.

Other evidence suggests that price volatility might increase by more than 50 percent in the absence of government support prices. A graph provided by Crain and Lee suggests that prices were two to three times more volatile under programs which resulted in a greater market orientation than under other program regimes. In the fourth scenario, it is assumed that prices are twice as volatile as assumed in the first two scenarios. The following is a summary of each scenario and all the assumptions (listed on pages 19 and 20) made in solving each one.

Scenario	1 Participation in Government Program, Target Price = $4.00	2 Participation in Government Program, Target Price = $3.17	3 No Government Program (50% higher volatility)	4 No Government Program (100% higher volatility)
Assumptions (pgs. 19 &20)	a - m	a - m	a - h j - n	a - h j - n

It is assumed that commercial storage costs 2¢/bu./month (see Anderson and Noyes). In addition, a producer incurs an opportunity cost of foregone interest by not selling the wheat. The initial interest rate is set at 10%, the average interest rate charged by the Bank for Cooperatives over the period 1974-1993 . Sensitivity of the results to alternate interest rates is discussed later.

Since no set-aside has been required for the last two years, the percent of base acres required to be set aside is set at zero. Also, it is assumed that program yield equals actual yield and that the predicted marketing year average price is correct (which implies that a payback situation never occurs).

Description of Data

The analysis in this thesis is a simulation of the marketing strategies that a producer maximizing a particular utility function would choose given a particular set of information. The empirical data required to conduct such a simulation are those used to estimate realistic values for the parameters in the simulation. Gulf price data are used as the cash prices in this estimation and are taken from the November 30 and June 20 Gulf delivery prices for U.S. hard-red winter wheat.[13] Although other parameters (e.g. yield and beginning and ending dates of the period) are based on central Oklahoma values, the change in Gulf prices from time 1 to time 2 is very similar to the change in local cash prices over this time. This change in price (from time 1 to time 2), and not the price level, is what determines strategy selection.

The futures prices used are the November 30 and the June 20 closing prices for the December contract on the Kansas City Board of Trade. If November 30 fell on a weekend or holiday the preceding trading day's closing price is used. Both the gulf and the futures prices are taken from data sets provided by Technical Tools.

U.S. monthly average prices, 5-month marketing weights, and marketing year average price marketing weights are taken from various issues (1974-1994) of the Agricultural Prices Summary published by the Economic Research Services.

CHAPTER IV

RESULTS

Results indicate that participation in the government deficiency payment program does not necessarily reduce hedging. Although the deficiency payment helps reduce revenue risk, marketing strategies are available that can reduce risk nearly as well as the deficiency payment program can. The biggest loss to producers from reducing deficiency payments is lost revenue and inter-year risk reduction.

With interest rates at 10% (the average over this period of time), the accrued interest revenue from selling the crop at harvest is 13.8¢/bu., netting a November 30 price of $3.21/bu (not counting the deficiency payment). For the optimal strategy to involve storage, the risk adjusted gain of that strategy (from June 20 until November 30) must be greater than this amount. This is because selling at harvest eliminates all price risk.

Tables 3 - 11 present results of four scenarios for three different levels of risk aversion using a mean-variance utility function. Table 3 indicates that producers with low risk aversion choose the same strategy in each scenario, storing wheat at harvest and selling it on November 30; no futures or options are used. The risk adjusted returns (not including the deficiency payment) are greater than $3.21/bu, making storage optimal.

Table 3: Optimal Post-Harvest Marketing Strategies: Low Risk Aversion; 10% Interest Rate; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Gov't Program (100% higher volatility)
Expected Return	$40,143 ($4.01/bu)	$32,809 ($3.28/bu)	$32,229 ($3.22/bu)	$32,229 ($3.22/bu)
Standard Deviation	$2,492	$2,988	$5,045	$6,767
Risk-Adjusted Return	$40,137	$32,800	$32,203	$32,184
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	$32,243 ($3.224)	$32,240 ($3.224)	$32,203 ($3.220)	$32,184 ($3.218)
Risk-reducing Benefit Lost	------	$3	$40	$59
Expected Deficiency and Findley Payments	$7,707	$553	$0	$0
Interest on Def. and Findley Payments	$187	$7	$0	$0
Percent Sold at Harvest	0	0	0	0
Futures Contract				
Put ($0.10 out-of-the-money)				
Put (at-the-money)				
Put ($.10 in-the-money)				
Call ($0.10 in-the-money)				

These results indicate that on average the market price increases by 5.04% from June 20 to November 30 while the opportunity cost of capital (with interest rates of 10%) over this period is 4.49%. Therefore, there is little difference (.55%) in the rate of return between selling at harvest and the optimal strategy of storing until November 30. The cash price used here is the Gulf price less $0.75/bu. transportation costs, approximating central Oklahoma prices.

As figure 6 shows, the payoff of the portfolio with a target price of $4.00 (storing the crop at harvest and receiving a deficiency payment) resembles that of a call option with a strike price of $4.00/bu. The main difference is that while the intrinsic value of a call option can never be worth less than $0.00/bu., the portfolio pictured here can never be worth less than $4.00/bu. If the marketing year average (MY) price decreases to $3.00/bu., the cash position decreases to $3.00/bu., but the deficiency payment increases to $1.00/bu. (4.00 - 3.00) making the portfolio worth $4.00/bu. However, if the MY price increases above $4.00/bu, the cash position value increases by the same amount while the deficiency payment becomes worthless, allowing dollar for dollar gains when prices rise above $4.00/bu.

This payoff becomes worth even more as volatility increases. Essentially, a call option gives its owner most of the benefits of rising prices and protects the owner from suffering the full cost of a drop in prices. Thus, a call option offers insurance against falling prices and holds out the promise of high profits from rising prices. The riskier the value of the underlying futures contract, the greater the chance of an extreme price movement. If prices fall dramatically, the insurance feature of the call option comes into

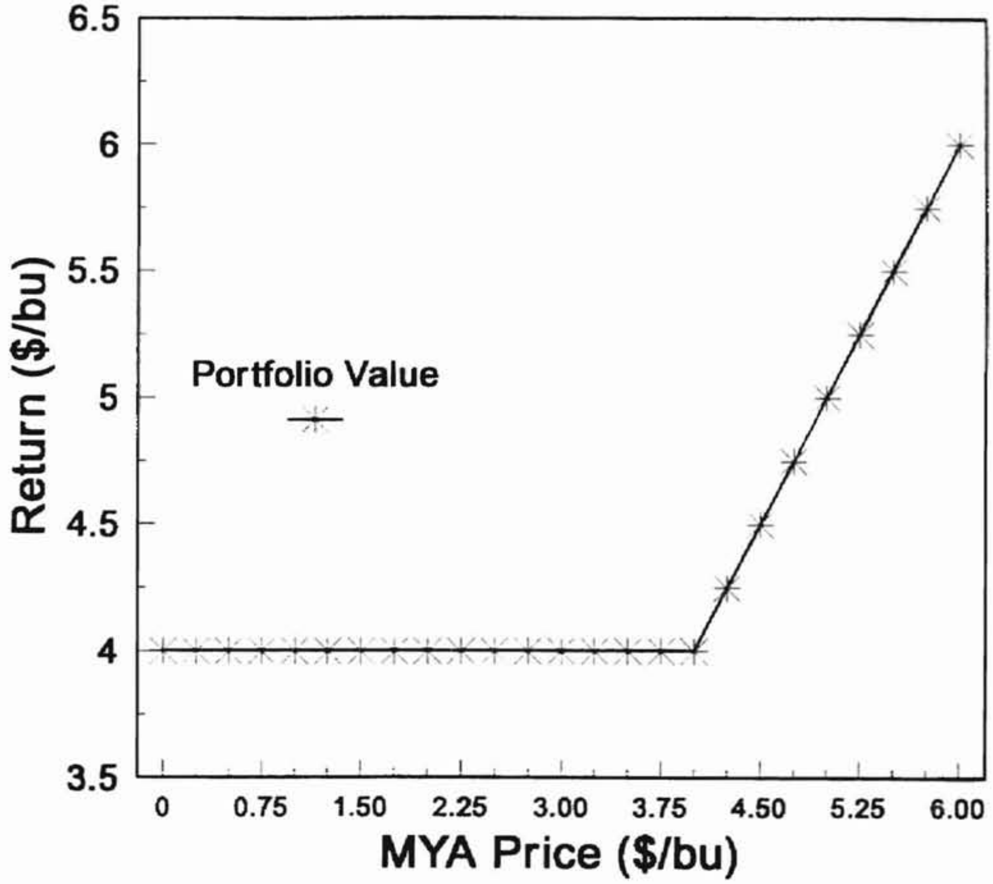

Figure 6. Portfolio Value with Crop Sold on November 30.

play limiting the call holder's loss. However, if prices increase dramatically, the call owner participates fully in the price increase. The protection against large losses, coupled with participation in large gains, makes call options more valuable when the underlying stock is risky (i.e. prices become more volatile).

Table 3 also shows that the standard deviation of returns, or risk, increases as deficiency payments are reduced or eliminated. The increased risk comes primarily from lowering or removing the "floor" on prices. With a $4.00 target price and a strategy of storing until November 30, returns could range from $3.22/bu. to $4.98/bu., depending on the year. With a $3.17 target price and the same strategy, that range is from $2.37/bu. to $4.61/bu. Thus, reducing the target price from $4.00 to $3.17 shifts the minimum price received downward by $0.85/bu. but shifts the maximum price received downward by only $0.37/bu. The range widens to $1.76/bu. to $5.34/bu. under the scenario with 50 percent higher price volatility, and to a range of $1.44/bu. to $6.17/bu. under the scenario with 100 percent higher price volatility. However, because the producer in table 3 cares little about risk, the effect on risk of reducing the deficiency payment is not enough to change the producer's optimal strategy.

The fifth line of each table records for each scenario the risk-reduction benefit lost by the producer when moving from the current program to that scenario. For example, the risk-adjusted return in the scenario with a target price of $4.00 is $40,137, while the risk-adjusted return with a $3.17 target price is $32,800. Subtracting the income effect of the deficiency payment from the risk-adjusted return gives the risk-reducing benefit of the payment. This is accomplished by taking the risk-adjusted return minus the deficiency payment and interest. These results are presented in the fourth line of each table.

The risk-reducing effect of each scenario (without the income effect of the deficiency payment) is compared to the $4.00 target price scenario and the results are shown in the fifth line of each table. Reducing the target price to $3.17, costs a producer with a low level of risk aversion and a cost of capital of 10%, $3.00 in risk protection. In the no-government-program scenario with 50% more volatile prices, an additional $40 of risk protection is lost, and in the 100% more volatile scenario a total of $59 of risk protection is lost. This small loss in risk-reduction benefit from reducing or eliminating the deficiency payment indicates that the main benefit of the deficiency payment is as an income supplement. These results support the idea that deficiency payments reduce risk and that use of futures and options could increase as target prices are reduced.

However, these results are sensitive to other factors. Table 4 indicates that a producer with medium risk aversion under the $4.00 target price scenario chooses a strategy of selling 50 percent of the wheat at harvest and storing the remaining 50 percent for sale in November. The risk-adjusted return of this strategy is greater than storing the entire crop ($39,940 compared to $39,832) or selling the entire crop at harvest ($39,940 compared to $39,775). However, the risk-adjusted return after subtracting the income effect of the deficiency payment is less than the return of selling at harvest, suggesting that the riskiness of each strategy is important to the producer's choice. The standard deviation of selling the entire crop at harvest (2,092) or storing the crop (2,492) is greater than the standard deviation of only selling half the crop at harvest (1,535). This is because of the offsetting effects of the crop in storage and the deficiency payment to changes in

Table 4: Optimal Post-Harvest Marketing Strategies: Medium Risk Aversion; 10% Interest Rate; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Gov't Program (100% higher volatility)
Expected Return	$40,058 ($4.01/bu)	$32,684 ($3.27/bu)	$32,079 ($3.21/bu)	$32,079 ($3.21/bu)
Standard Deviation	$1,535	$890	$0	$0
Risk-adjusted Return	$39,940	$32,644	$32,079	$32,079
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	32,046 ($3.205)	$32,084 ($3.208)	$32,079 ($3.208)	$32,079 ($3.208)
Risk-reducing Benefit Lost[a]	-------	$38	-$33	-$33
Expected Deficiency and Findley Payments	$7,707	$553	$0	$0
Interest on Def. and Findley Payments	$187	$7	$0	$0
Percent Sold at Harvest	50	50	100	100
Futures Contract				
Put ($0.10 out-of-the-money)				
Put (at-the-money)				
Put ($.10 in-the-money)				
Call ($0.10 in-the-money)		sell 1 contract		

[a]Negative numbers indicate that risk-reduction benefits are gained, not lost, when deficiency payment is reduced.

price. The stored crop protects the value of the deficiency payment from increasing prices, and the deficiency payment protects the value of the stored crop from decreasing prices.

In this scenario, selling the wheat would eliminate all price risk, but the producer would be subject to the risk that the deficiency payment would decrease if prices increase. Storing a portion of the wheat helps offset that risk. Thus, storing wheat is used to hedge the deficiency payment. Storage is used as a hedge instead of buying a futures contract, buying a call, or selling a put, because it is cheaper. Since the cash price increases at roughly the cost of storage (with interest rates at 10%), the expected return from storing wheat is approximately equal to storage and interest costs. Because time 1 futures price is an unbiased predictor of the time 2 futures price, the expected return from a futures or options position is a loss equal to the transaction costs. Thus, storing a portion of the wheat protects the deficiency payment from increasing prices thereby decreasing the standard deviations of returns at near-zero cost.

Although the deficiency payment is hedged, it appears that less than the entire quantity is hedged, since the deficiency payment is for 10,000 bu. and a futures contract is written on 5,000 bushels. However, since on average 58% of the MY price is determined in the first 5 months of the marketing year, this position is nearly fully-hedged. This can be illustrated by considering the following example. If the cash and futures prices increase by \$.20/bu. from June through November, the value of the futures contract increases by \$.20 for the 5,000 bushels, which translates into a \$.10 increase for the 10,000 bushels. Meanwhile, the deficiency payment has decreased by approximately \$.10/bu. since only

58% of the price movement that takes place in the first 5 months affects the realized marketing year average price. The resulting payoff is plotted in figure 7. The graph of 50% sold at harvest shows that the gain from decreasing prices in the deficiency payment is offset by the loss from the grain in storage. As with any hedged position, if prices move favorably the gain is forfeited.

Table 4 also shows that if the target price is reduced to \$3.17, the producer sells half of the crop at harvest and sells one in-the-money call. The crop in storage hedges the deficiency payment against increases in prices; however, since the target price is reduced to \$3.17, the floor on prices is reduced by \$0.83. By selling an in-the-money call (strike price = \$3.51), the producer receives a premium of \$0.19/bu. which has the effect of raising the target price to \$3.36 when the futures price is \$3.51 or below. When futures prices are above \$3.51/bu., the option will be exercised decreasing the target price to \$3.17 as the futures price approaches \$3.61 and above. Since option markets are efficient, the initial premium equals the average of the distribution of ending intrinsic values. Therefore, futures and options are bought and sold to reduce risk while sacrificing some amount of expected return. According to the producer's level of risk aversion, a tradeoff of reduced risk for expected return is made such that the optimal strategy is the one with the greatest risk-adjusted return. In this case, selling 50% of the crop at harvest and an in-the-money call provides the optimal risk/return tradeoff given a target price of \$3.17. A strategy that would accomplish the same result would be to hedge the deficiency payment by storing a smaller portion (e.g. 25%) of the crop until November 30. With such a strategy, a call would not have to be sold to protect the crop in storage.

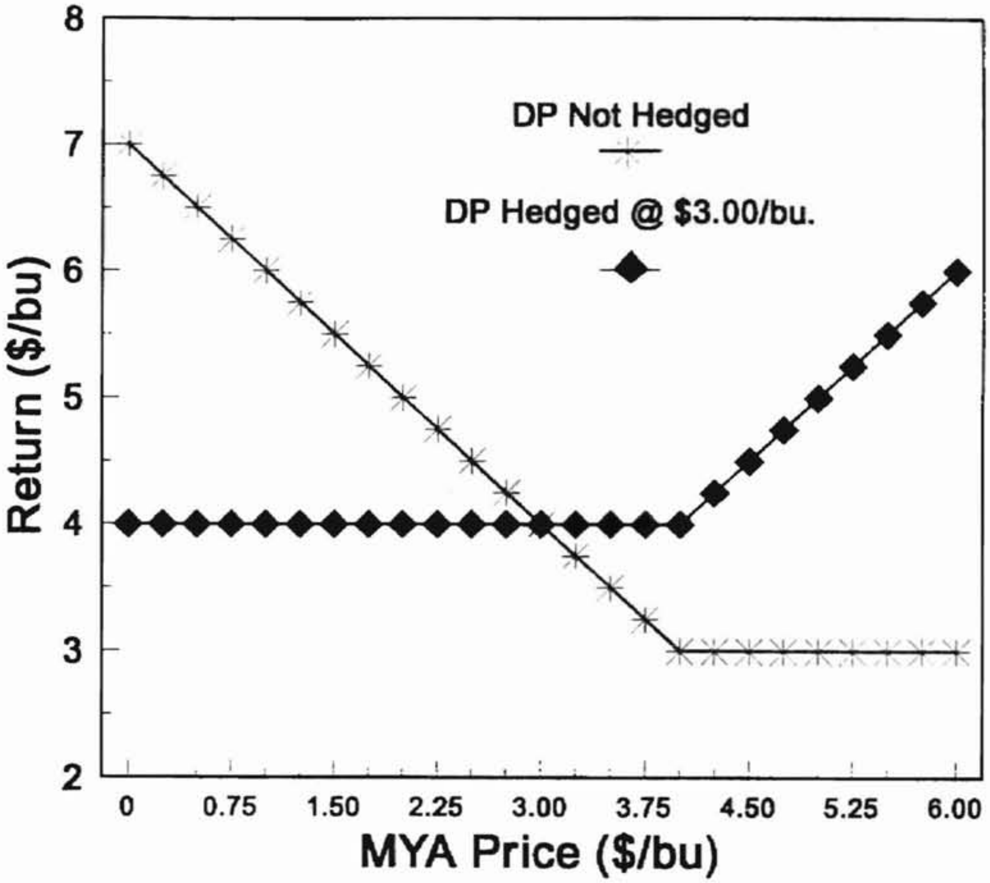

Figure 7. Portfolio Value: Crop Sold at Harvest for $3.00/bu.

In the no-government program scenarios, the optimal strategy is to sell the entire crop at harvest. Without the added risk of the deficiency payment, the certain return of selling at harvest ($30,079) is greater than the risk-adjusted return of storing until November 30 ($30,806 with 50% greater volatility and $29,939 with 100% greater volatility).[14]

The results with no government program apply to current legislation that replaces the deficiency payment with a payment that is not determined by market prices or that does not require set-aside acres. Such a payment would provide a certain revenue (eliminating the need to hedge the uncertain MY price), resulting in an optimal strategy determined by the physical cost of storage and opportunity cost of capital. Since on average the market price increases only slightly more than the average opportunity cost of capital and storage, futures and options positions are not part of the optimal strategy. For futures and options to be used, there would have to be a larger return to storage. This could result from a lower than average opportunity cost of capital or a cost of storage less than 2¢/bu./month. Then, as risk aversion increased, producers could use futures or options to reduce the risk of storage while still capturing the higher return of storage.

Table 5 indicates that the optimal strategy for producers with high risk aversion is to sell half of their crop at harvest if the target price is $4.00. The risk-adjusted returns of this strategy, ignoring the deficiency payment, is less than the certain return of selling at harvest. However, the risk from the uncertain deficiency payment actually causes the risk reduction of this scenario to be less than the scenarios without the government program. Therefore, the optimal strategy involves storage because it hedges the deficiency payment

Table 5: Optimal Post-Harvest Marketing Strategies: High Risk Aversion; 10% Interest Rate; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Gov't Program (100% higher volatility)
Expected Revenue	$40,058 ($4.01/bu)	$32,577 ($3.23/bu)	$32,079 ($3.21/bu)	$32,079 ($3.21/bu)
Standard Deviation	$1,535	$607	$0	$0
Risk-adjusted Return ($/bu)	$39,705	$32,521	$32,079	$32,079
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	$31,811 ($3.181)	$31,961 ($3.196)	$32,079 ($3.208)	$32,079 ($3.208)
Risk-reducing Benefit Lost[a]	-----	-$150	-$268	-$268
Expected Def. and Findley Payments	$7,707	$553	$0	$0
Interest on Def. and Findley Payments	$187	$7	$0	$0
Percent Sold at Harvest	50	100	100	100
Futures Contract				
Put ($0.10 out-of-the-money)		sell 1 contract		
Put (at-the-money)				
Put ($.10 in-the-money)				
Call ($0.10 in-the-money)				

[a]Negative numbers indicate that risk-reduction benefits are gained, not lost, when deficiency payment is reduced.

against increasing prices while increasing in expected value at roughly the cost of storage and interest.

When the target price is reduced to $3.17, the optimal strategy is to sell the entire crop at harvest and buy an out-of-the money put. Even though the target price is reduced, the deficiency payment still increases risk since there is no offsetting cash position. A put is sold to hedge the deficiency payment against increasing prices, reducing the standard deviation of returns to $607. If the optimization algorithm had permitted it, a strategy with similar risk-adjusted returns for this scenario would have been to sell 75% of the crop at harvest, with no futures or options. The 25% of the crop in storage would hedge the deficiency payment against increases in price, while the expected gain in cash price from time 1 to time 2 would offset the cost of the protection (storage and interest).

In the no-government-program scenarios, the optimal strategy is to sell the entire crop at harvest. This locks in a price, avoids storage cost and earns interest over the time period, but passes up the opportunity to gain from price increases. There is no deficiency payment, so no hedging positions are needed to offset this risk.

Thus, subtracting the income-increasing features of the deficiency payment program and looking only at the risk-reduction benefit, producers' risk-adjusted returns change little as target prices are reduced or eliminated. Hedging and other cash market strategies provide adequate risk management. Furthermore, for producers with a low or medium risk aversion level over all government program scenarios, the loss in risk-adjusted returns from choosing the sub-optimal strategy of selling wheat at harvest and doing nothing else ranges between one and four cents per bushel. Some producers may be willing to give up that relatively small amount in order to avoid having to allocate additional effort to marketing strategies rather than to production activities.

The above results assume commercial storage costs of 2.0¢/bu./month, and a cost of capital of 10%. Ten percent represents the average rate charged by the bank of cooperatives over the time period considered and probably represents the lowest rate that producers who borrow from commercial banks received over this period.

Additional results show that using a higher cost of capital would change the optimal strategies. With an average cost of capital of 11%, for example, the opportunity cost of storage increases to 15.5¢, requiring a November 30 price of $3.22/bu. to break even. Since this price is approximately equal to the expected November 30 price, the optimal strategy for producers who face an average cost of capital >= 11% would be to sell at harvest (after the expected return is discounted for risk, it would be less than the opportunity cost of capital). Also, if storage costs increase by 1¢/bu./month with interest rates at 10%, the optimal strategies are the same as increasing the interest rates to 11% while storage costs are 2 cents/bu./month.

Tables 6-8 show the optimal strategies for the three different levels of risk aversion considering an average interest rate of 12%. Table 6 shows that the higher storage costs (from the increased interest rates) makes it optimal to sell at harvest. No market-based strategies are used for producers with low levels of risk aversion. This indicates that interest rates determine whether to sell the crop at harvest or store until November 30 and risk aversion determines whether the deficiency payment should be hedged.

The results in table 7 indicate that the optimal strategy for all scenarios includes

Table 6: Optimal Post-Harvest Marketing Strategies: Low Risk Aversion; Interest Rate = 12%; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Gov't Program (100% higher volatility)
Expected Revenue	$40,818 ($4.08/bu)	$33,771 ($3.38/bu)	$32,759 ($3.28)	$32,759 ($3.28/bu)
Standard Deviation	$2,609	$1,054	$0	$0
Risk-Adjusted Return ($/bu)	$40,804	$33,769	$32,759	$32,759
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	$33,579 ($3.358)	$33,293 ($3.333)	$32,759 ($3.276)	$32,759 ($3.276)
Risk-Reducing Benefit lost	-----	$287	$820	$820
Deficiency Payment	$7,224	$476	0	0
Percent Sold at Harvest	100	100	100	100
Futures Contract				
Put ($.10 out-of-the-money)				
Put (at-the-money)				
Put ($.10 in-the-money)				
Call ($.10 in-the-money)				

Table 7: Optimal Post-Harvest Marketing Strategies: Medium Risk Aversion; Interest Rate = 12%; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Gov't Program (100% higher volatility)
Expected Revenue	$40,748 ($4.07/bu)	$33,248 ($3.32/bu)	$32,759 ($3.28/bu)	$32,759 ($3.28/bu)
Standard Deviation	$1,405	$681	$0	$0
Risk-Adjusted Return ($/bu)	$40,451	$33,178	$32,759	$32,759
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	$33,227 ($3.332)	$32,702 ($3.270)	$32,759 ($3.276)	$32,759 ($3.276)
Risk-Reducing Benefit Lost	-----	$48	$467	$467
Deficiency Payment	$7,224	$476	0	0
Percent Sold at Harvest	100	100	100	100
Futures Contract	buy 1 contract			
Put ($.10 out-of-the-money)				
Put (at-the-money)		sell 1 contract		
Put ($.10 in-the-money)				
Call ($.10 in-the-money)				

selling wheat at harvest, since the cost of storage is greater than the return. Due to the increased level of risk aversion, the optimal marketing strategies include the use of futures or options to hedge the deficiency payment. These strategies are the same as those that are optimal with 8% interest rates and a high level of risk aversion. A futures contract is used to hedge the deficiency payment with a target price of $4.00, while a put is sold to hedge the deficiency payment with a target price of $3.17. The only difference is that with a medium level of risk aversion, an "at-the-money" put is sold instead of an "out-of-the-money" put in the high risk scenario. The "at-the-money" put is riskier since there is a greater chance that it will be exercised than the "out-of-the-money" put. This greater amount of risk leads to a higher premium, which would be more important to an individual who discounts returns less for risk. With no government program, the deficiency payment is no longer risky, eliminating the need for futures or options.

Table 8 indicates that a producer with high risk aversion sells wheat at harvest under all four scenarios for the same reason as discussed in Table 7. However, the optimal use of futures and options changes to selling an "in-the-money" put and buying an "in-the-money" call for a target price of $4.00 and selling an "out-of-the-money" put for a target price of $3.17. The portfolio payoff under a $4.00 target price (selling at harvest and buying a call) resembles that of a put; however, the minimum portfolio value is increased by selling the put. The minimum portfolio payoff under a $3.17 target price is also increased by selling a put, but this also limits the gain in the deficiency payment from decreasing prices. The higher level of risk aversion changed the strike price of the put from "at-the-money" to "out-of-the-money". This option is less risky since prices have to

Table 8: Optimal Post-Harvest Marketing Strategies: High Risk Aversion; Interest Rate = 12%; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Gov't Program (100% higher volatility)
Expected Revenue	$40,650 ($4.82/bu)	$33,236 ($4.07/bu)	$32,759 ($3.28/bu)	$32,759 ($3.28/bu)
Standard Deviation	$1,337	$653	$0	$0
Risk-Adjusted Return ($/bu)	$37,965	$32,596	$32,759	$32,759
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	$30,741 ($3.074)	$32,120 ($3.212)	$32,759 ($3.276)	$32,759 ($32,759)
Risk-Reducing Benefit Lost[a]	-----	-$1,378	-$2,018	-$2,018
Deficiency Payment	$7,224	$476	0	0
Percent Sold at Harvest	100	100	100	100
Futures Contract				
Put ($.10 out-of-the-money)		sell 1 contract		
Put (at-the-money)				
Put ($.10 in-the-money)	sell 1 contract			
Call ($.10 in-the-money)	buy 1 contract			

[a]Negative numbers indicate that risk-reduction benefits are gained, not lost, when deficiency payment is reduced.

go down $.10 more before it becomes a liability.

If producers faced a lower than average cost of capital over this time period, the optimal strategies would also be different than those under the 10% scenario. Table 9 shows that the optimal strategy for producers with a low level of risk aversion and an opportunity cost of capital of 8% is to store the crop until November 30. Since returns are discounted little for risk and the opportunity cost of storage is reduced, the risk-adjusted gain from storing is greater than the certain return from selling at harvest.

Table 10 presents the results for producers with a medium level of risk aversion; the optimal strategy with a target price of $4.00 is to store the entire crop until November 30. The increased risk aversion decreases the risk-adjusted return but not by enough to make the use of futures or options optimal. If the target price is reduced to $3.17, the optimal strategy is to store all of the crop and sell one futures contract and one in-the-money call. The futures contract and call provide price protection against decreasing prices, indicating that a reduction in target price leads to increased hedging to reduce the risk. In the 50% and 100% higher volatility scenarios, the optimal strategy is to sell all the crop at harvest, which eliminates risk but forgoes potential gain in price after harvest. The increased risk aversion discounts the risk-adjusted returns of storage to less than the certain return from selling at harvest.

The optimal strategy for producers with a high level of risk aversion (Table 11) involves selling all the wheat at harvest, under all four scenarios. This locks in a price, avoids storage cost and earns interest over the time period, but passes up the opportunity to gain from price increases. However, the uncertain deficiency payment, which is no

Table 9: Optimal Post-Harvest Marketing Strategies: Low Risk Aversion; Interest Rate = 8%; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Gov't Program (100% higher volatility)
Expected Revenue	$40,228 ($4.02/bu)	$32,964 ($3.30/bu)	$32,442 ($3.24/bu)	$32,442 ($3.24/bu)
Standard Deviation	$2,223	$2,946	$3,370	$4,986
Risk-Adjusted Return ($/bu)	$40,220	$32,951	$32,442	$32,442
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	$32,996 ($3.300)	$32,475 ($3.248)	$32,442 ($3.244)	$32,442 ($3.244)
Risk-Reducing Benefit Lost	-----	$521	$554	$554
Expected Deficiency and Findley Payments	$7,224	$476	0	0
Percent Sold at Harvest	0	0	0	0
Futures Contract				
Put ($.10 out-of-the-money)				
Put (at-the-money)				
Put ($.10 in-the-money)				
Call ($.10 in-the-money)				

Table 10: Optimal Post-Harvest Marketing Strategies: Medium Risk Aversion; Interest Rate = 8%; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Government Program (100% higher volatility)
Expected Revenue	$40,228 ($4.02/bu)	$32,845 ($3.28/bu)	$32,302 ($3.23/bu)	$32,073 ($3.21/bu)
Standard Deviation	$2,224	$1,251	$798	$0
Risk-Adjusted Return ($/bu)	$39,486	$32,610	$32,207	$32,073
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	$32,262 ($3.226)	$32,134 ($3.213)	$32,207 ($3.221)	$32,073 ($3.207)
Risk-Reducing Benefit lost	-----	$127	$55	$55
Deficiency Payment	$7,224	$476	0	0
Percent Sold at Harvest	0	0	0	100
Futures Contract		sell 1 contract	sell 2 contracts	
Put ($.10 out-of-the-money)				
Put (at-the-money)				
Put ($.10 in-the-money)				
Call ($.10 in-the-money)		sell 1 contract		

Table 11: Optimal Post-Harvest Marketing Strategies: High Risk Aversion; Interest Rate = 8%; Mean-Variance Utility Function.

	Gov't Program; Target Price = $4.00/bu.	Gov't Program; Target Price = $3.17/bu.	No Gov't Program (50% higher volatility)	No Gov't Program (100% higher volatility)
Expected Revenue	$39,788 ($4.73/bu)	$32,528 ($3.25/bu)	$32,073 ($3.21/bu)	$32,073 ($3.21/bu)
Standard Deviation	$1,346	$634	$0	$0
Risk-Adjusted Return ($/bu)	$37,070	$31,924	$32,073	$32,073
Risk-Adj. Return w/o Income of Def. Pymt.($/bu)	$29,846 ($2.985)	$31,448 ($3.145)	$32,073 ($3.207)	$32,073 ($3.207)
Risk-Reducing Benefit Lost[a]	-----	-$1,720	-$2,502	-$2,502
Deficiency Payment	$7,224	$476	0	0
Percent Sold at Harvest	100	100	100	100
Futures Contract	buy 1 contract			
Put ($.10 out-of-the-money)		sell 1 contract		
Put (at-the-money)				
Put ($.10 in-the-money)				
Call ($.10 in-the-money)				

[a]Negative numbers indicate that risk-reduction benefits are gained, not lost, when deficiency payment is reduced.

longer offset by a cash position, increases risk. With a target price of $4.00, a futures contract is bought to provide protection against increasing prices. Under a reduced target price, the expected deficiency payment is smaller ($0.046/bu.) and the producer can effectively hedge this smaller amount by selling an out-of-the-money put.

Under the current program, the amount of any deficiency payment is not known at harvest when the wheat is sold, and is thus risky; the risk averse producer finds that reducing the government deficiency payment reduces risk. In fact, after netting out the income-enhancing aspect of the deficiency payment, the highly risk averse producer, across all levels of opportunity costs, actually gains risk-reduction benefit when the target price is reduced from $4.00 to $3.17.

The actual strategies chosen are sensitive to the assumptions about interest rate, storage costs, utility specification, and other parameters of the model. But the expected values of the top strategies are similar enough that even when the optimal strategies may differ, the risk-adjusted return does not change substantially. As producers' opportunity cost of capital and/or level of risk aversion increase, they find it optimal to sell at harvest to eliminate the price risk associated with storage. This leaves the deficiency payment vulnerable to increasing prices; so, it is hedged using storage, futures or options. (Additional results, not reported here, using the Cox-Rubinstein utility function support this finding. The exact combination of hedging instruments used was different using the Cox-Rubinstein utility function, but the overall results from this function were the same.)

This sensitivity of choice of marketing strategy to varied model specifications suggests that the simulation reflects a market that is reasonably consistent with the law of one price. As a consequence, producers are unlikely to find marketing strategies that perform substantially better on average than selling wheat at harvest, unless they have extra, year-specific information.

To summarize, after subtracting the income-increasing features of the deficiency payment program and looking only at the risk-reduction benefit, producers with low levels of risk aversion lose small amounts of risk-adjusted revenue when target prices are reduced or eliminated. Producers with medium or high levels of risk aversion may gain or lose risk-reduction benefit, depending on the scenario. A far bigger loss to producers is the revenue-increasing aspects of the deficiency payment program, although this loss would be smaller than reported here if participating in the government program required a set-aside of eligible acres.

CHAPTER V

CONCLUSIONS

The deficiency payment performs two primary functions when included in a producer's post-harvest marketing strategy: a) risk reduction and b) income support. When combined with storage of the crop, the deficiency payment establishes a payoff similar to a call option. If prices decrease, the declining value of the cash position is offset by the increase in value of the deficiency payment. When prices increase, the deficiency payment decreases while the value of the cash position increases dollar for dollar with market prices. Risk associated with storing wheat is reduced since the deficiency payment protects against decreasing prices. As target price is reduced or the deficiency payment program is eliminated the entire stored crop is no longer protected.

However, since the value of the deficiency payment is not known until the end of the marketing year, it actually increases the level of risk for producers with medium or high levels of risk aversion. This is because the cash price increases on average from harvest to November 30 by roughly the cost of storage and capital. At higher risk aversion levels, the optimal strategy is to sell all wheat at harvest because it provides a certain return nearly equal to the return from storage (not discounted for risk). If producers sell all their wheat at harvest, the deficiency payment is no longer protected against increasing prices. These producers find it optimal to reduce the risk of the deficiency payment by storing part of their crop, buying a futures contract or a call, or selling a put. As target prices are reduced or payments not connected to the market price are made, producers will store less and/or use fewer futures and options contracts. They no longer need to hedge the uncertainty of the deficiency payment.

However, storage costs and cost of capital affect this relationship. If a producer faces a cost of capital less than the market average (10% was the average cost of capital over this time period) or a cost of storage less than 2¢/bu./mo., there is more incentive to store. With a cost of capital 2% less than the average and for higher levels of risk aversion, the optimal strategies under the deficiency payment scenarios involve storage while the optimal strategies in the higher volatility scenarios still involve selling the crop at harvest. With the lower opportunity cost of capital, the risk-adjusted return from storage is enough greater than the return from selling at harvest that these producers increase their use of futures and options to provide the stored crop with price protection that would otherwise be provided by the deficiency payment. A similar effect is observed when storage cost is decreased.

With a cost of capital greater than the market average, the expected return from storing becomes less than the associated cost. For example, with a cost of capital 2% above the average, the optimal strategy for all levels of risk aversion is to sell at harvest. The higher the expected deficiency payment value and the higher the producer's level of risk aversion, the more likely the producer will hedge the deficiency payment. Reducing the target price decreases the expected value of the deficiency payment and its associated risk, causing risk averse producers to decrease use of futures and options to hedge the deficiency payment. Less risk averse producers do not hedge the deficiency payment, due to the potential gain if prices decrease.

The risk-reducing portion of the deficiency payment can almost always be replaced with futures and/or options, or by selling at harvest. This is due to the similarities between the payoff of the deficiency payment and a put option (which can also be emulated using other combinations e.g. selling a futures contract and buying a call option). When the optimal marketing strategy includes selling at harvest, the unprotected deficiency payment actually increases the risk of the portfolio even when compared to the "no-government-program" scenarios.

This leads to the other main function of the deficiency payment - income support. From the producer's perspective, this is the greatest loss from reducing or eliminating target prices. The target price encourages production to be greater than quantity demanded in years of low prices (cash price below target price). The market price for the resulting amount of grain is determined by the market demand curve. The difference between the resulting market price and the target price is made up by the government in the form of deficiency payments. Therefore, the market determines price while the program payment is an additional income determined by the difference between the resulting market-determined price and the target price. The deficiency payment varies as prices vary, making the deficiency payment more of an intra-year revenue assurance program than an intra-year risk reduction tool. Since the target price does not vary from year to year, the deficiency payment provides an inter-year risk reduction not available in futures and options markets. These markets do not offer a long-term contract that would provide a guaranteed price over the period of several years.

Although there are costs associated with participating in the government program (e.g. acreage set aside requirements and other compliance restrictions), the program provides a guaranteed minimum price at a relatively low cost to the producer. This can be observed by looking at the expected revenue of marketing strategies consisting only of participating in the government program compared to strategies using options and/or futures. The expected revenue from participating in the government program is greater than the expected revenue of using market strategies by at least the amount of the deficiency payment. This is because the government is covering the "premium" of the deficiency payment program while producers have to pay the initial premium to get the same benefit in the futures or options market.

To summarize: for a producer with low risk aversion at 8%, 10%, and 12% interest rates, reducing the target price or eliminating the government deficiency payment program does not affect the optimal post-harvest wheat marketing strategy. For a producer with a medium level of risk aversion and an opportunity cost of capital of 10% or 12%, the optimal strategy involves selling at harvest and hedging the deficiency payment by storing part of the crop or selling a put option. Reducing the target price or eliminating the government program reduces or eliminates the uncertain deficiency payment, causing these producers to decrease their use of futures and options. With a lower opportunity cost of capital (8%), the increased return from storage causes a producer to store the entire crop. To make up for the reduced target price, risk-reduction for the crop in storage is provided by selling a futures contract and a call option. In this case, reducing or eliminating the deficiency payment leads to increased use of futures and options.

For a producer with a high level of risk aversion and an opportunity cost of capital of 8%, 10%, or 12%, the optimal strategy includes selling at harvest. Since the uncertain deficiency payment is risky, reducing or eliminating this payment decreases or eliminates the need to protect it with storage, futures, or options.

Thus, while some producers will find it advantageous to increase their use of futures and options if target prices and government price supports are reduced, others may not. Some likely will reduce risk by selling at harvest instead of storing for later sale, particularly if they face relatively high capital or storage costs.

These results are similar to previous findings concerning marketing strategies in the presence of deficiency payments. The desirability of selling the crop at harvest in the presence of high opportunity costs of capital and/or high levels of risk aversion are the same results that Anderson and Adam found in their study concerning wheat marketing. However, by explicitly considering the time value of the deficiency payment, it was found that the deficiency payment actually increases the level of risk for these producers, causing them to use storage, futures, or options to reduce this risk.

Similarly, Heifner et al. had stated that intra-year income stability could be provided by market-based strategies. This coincides with the findings here that with a high opportunity cost of capital and/or high levels of risk aversion, the deficiency payment actually increases risk over the no-government-program scenarios that use only market-based strategies. However, Heifner et al. noted that market-based strategies could not replace the inter-year stability provided by the deficiency payment program. This study has examined post-harvest marketing strategies within a marketing year. It has not considered the effects on year-to-year variation in prices, and the associated risk in long-term investment decisions, of reducing or eliminating target prices.

Results in this study differ somewhat from the findings of Turvey and Baker who looked at marketing strategies under different government programs for corn and soybean producers. They found that the deficiency payment program reduced hedging by corn producers and that the loan rate reduced hedging by soybean producers. However, due to the differences in returns to storage, length of time being considered, patterns of seasonality, and modeling of the deficiency payment program, results are not directly comparable. By not considering the time value of the deficiency payment, the need for producers with a high opportunity cost of capital to hedge the deficiency payment was ignored in that study.

Endnotes

1. Contracts are sold in 5,000 bushel increments causing producers with production not divisible by 5,000 to either leave a portion of production unhedged or to be in a speculating position with more hedged than actually produced. Also, since not all months have a corresponding futures contract, larger basis risk can result if a more distant month must be used.

2. It is based on a five-year average of either a proven farm-yield or a county yield.

3. There are advance payments made in March and December. If a market option were used payment could not be received until July; thus the early payments can earn interest.

4. The deficiency payment is based on a 5-year average yield; therefore, current yields do not influence the current deficiency payment nor do they influence the value of a purchased put option.

5. Unlike futures contracts that specify the number of bushels, the deficiency payment covers the bushels produced on the base acres. But since the yield and number of acres are predetermined, the deficiency payment is based on a fixed number of bushels.

6. Section 1742 of the Food Security Act of 1985 called for the USDA to study the manner in which farmers might use futures and options markets, the extent of the price stability and income protection that producers might expect to receive from such participation, and the Federal budgetary impact of such participation.

7. Although Oklahoma prices are typically less than Gulf prices, there will not be any difference in the optimal marketing strategy as long as local basis is constant. The main component of a local basis is transportation cost and it remains relatively constant especially over the duration of the model (5 months).

8. It is recognized that the December option expires before this date. However, changing the ending date of the model does not significantly affect the results.

9. Although some research suggests that prices are not distributed lognormally, lognormality is assumed here for convenience.

10. This changed in 1996 to 6 major classes of wheat. White wheat was divided into two categories: hard white wheat and soft white wheat (USDA-FGIS)

11. Empirically, this is accomplished by setting the June 20 futures price equal to the mean of the distribution of November 30 futures prices, and by setting initial options premiums equal to their computed value over the period of simulation. This method of premium valuation is similar to stock option pricing models that consider a range of ending prices when valuing the option. Thus, the premium includes an implicit measure of

the time value associated with the option.

However, the data indicate that on average the futures price rose 3¢ per bushel from June 20 to November 30. In some years the price dropped, and in some years the price rose, but if a producer had purchased a futures contract on June 20 and sold it on November 30 every year from 1974 to 1993, the average profit would have been 3¢ per bushel. Since there is no assurance that this will continue, and because even if it did continue there would be some years when such a strategy would lose money, this study does not recommend such a risky strategy. However, if a producer believes that futures prices will rise following harvest, a less risky strategy is to buy call options at harvest. For the initial cost of the premium, the producer can profit if prices rise, but will not lose any additional money if prices drop. This strategy would be considered speculation, not hedging, by the Internal Revenue Service.

12. This reduces the intrinsic value of the deficiency payment "option" and increases its time value, since it is nearly "at-the-money".

13. For the years when November 30 or June 20 fell on a weekend or holiday, the last trading day before November 30 or June 20 was used.

14. These values are calculated using table 1 values for expected return and standard deviation for the strategy of storing until November. For 50% higher volatility, CE = $32{,}229 - (.0001/2) \times (5{,}045)^2 = 30{,}806$, and CE = $32{,}229 - (.0001/2) \times (6{,}767)^2 = 29{,}939$.

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