Optimal decision rules for marketing and storage of wheat and corn
by James William Mjelde

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Applied Economics
Montana State University

Abstract:
Expected profit maximizing decision rules for marketing and storage of winter wheat and corn were determined in this study. Decision alternatives considered were: 1) sell the crop at time of harvest, 2) go into the Farmer Owned Reserve, 3) take out a regular CCC loan on the crop and 4) store the grain without any federal loans taken out on the crop. The optimal decision rules, which were obtained from a stochastic dynamic programming model, depend on grain prices and the type of program under which the grain is held. Validity of the decision rules depend on future validity of the time series model for grain prices that were used to estimate Markovian transition probabilities.

Results indicate that the Farmer Owned Reserve can increase the value of a bushel of grain to an individual producer. When market prices are low for both winter wheat and corn a producer should enter the Farmer Owned Reserve. If market prices are high at either harvest or after harvest a producer should sell.

Unconditional and conditional probabilities of being in the various marketing alternatives while following the optimal policy were calculated. These probabilities show that if producers follow the optimal policy, a large amount of the U.S. grain crop will be held in the FOR program for the duration of the three year FOR contract.

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ABSTRACT

Expected profit maximizing decision rules for marketing and storage of winter wheat and corn were determined in this study. Decision alternatives considered were: 1) sell the crop at time of harvest, 2) go into the Farmer Owned Reserve, 3) take out a regular CCC loan on the crop and 4) store the grain without any federal loans taken out on the crop. The optimal decision rules, which were obtained from a stochastic dynamic programming model, depend on grain prices and the type of program under which the grain is held. Validity of the decision rules depend on future validity of the time series model for grain prices that were used to estimate Markovian transition probabilities.

Results indicate that the Farmer-Owned Reserve can increase the value of a bushel of grain to an individual producer. When market prices are low for both winter wheat and corn a producer should enter the Farmer Owned Reserve. If market prices are high at either harvest or after harvest a producer should sell.

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Chapter 1

INTRODUCTION

Grain producers are now faced with several grain marketing alternatives; they can sell their crop at the time of harvest, store their grain, go into the Farmer Owned Reserve (FOR), or take out a regular CCC loan on the crop. Each of these alternatives has different expected benefits and cost. For example, if a producer sells at harvest he will incur no storage cost or interest on loans taken out on the crop, but the market price the producer will receive is usually at its low point in its yearly cycle, due to the increased supply.

The primary objective of this study was to determine the optimal grain storage and marketing strategy[1] for an expected profit maximizing producer faced with the above alternatives. Although this problem has been submitted to cursory economic analysis by several researchers (see, for example, Johnson, Rizzi, Short, Fulton (1982); Meyers and Ryan (1981); Steele (1981); and McConnen, Stauber, Baldridge and Taylor (1982)), it has not been analyzed with the rigorous multiperiod optimization techniques.[2]

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[1] For brevity, "marketing strategy" will henceforth be used to refer to the joint grain-storage, grain-marketing strategy.

[2] Several studies (Gustafson (1958); Burt, Koo and Dudley (1980); Cochrane and Danin (1976); Alaouze et al. (1978, 1979); Kennedy (1979); Taylor and Talpaz (1979)) have employed rigorous optimization techniques to address grain storage and grain release at the national level. However, results from these studies are not applicable to the individual producer's problem for several reasons.

The study was comprised of two parts. One part was to develop time-series models to describe price movements for winter wheat and corn. These time-series models were used to calculate price transition probabilities for a stochastic dynamic programming (DP) model, which provided the foundation for the second part of the study. The DP model was used to find the decision rule that maximized the expected present value of profit over a three-year period, given the decision alternatives of: (a) sell at harvest; (b) privately store the grain; (c) participate in the 1982 CCC loan program; and (d) participate in the 1982 FOR program. At harvest time, the decision is based on current and past market prices. Starting the first month after harvest and each month thereafter, the decision for that month is based on the type of program under which the grain is held as well as current and past market prices. It should be cautioned that the validity of the decision rule depends on the future validity of the transition probabilities.

Dynamic programming was selected as the optimization technique because it is a powerful analytical and computational method for handling Markovian multistage decision processes (Burt (1982), and

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First, these studies incorporated price response, whereas the price received by an individual does not depend on the quantity he stores or sells. Second, storage decisions were assumed to be made yearly, while much shorter decision periods are appropriate for individuals. Third, the aggregate studies focused on determining an optimal national program, while this study focuses on optimal marketing strategies given the national programs for the 1982 crop.

Burt and Allison (1963)).[3] Furthermore, stochastic DP is by far the most efficient method for solving stochastic multistage optimization problems.

This study is divided into five chapters. The first chapter is an introduction. The second chapter gives a detailed discussion of the alternatives facing a producer. In this chapter the provisions of the regular CCC loan and FOR programs relevant to this study are discussed. The third chapter deals with the methodology used in developing the time-series models for winter wheat and corn, and the DP model. Assumptions used in the study are summarized in Chapter Four. Then the results of various DP solutions are discussed. Chapter five discusses limitations of the study and recommendation for further study.

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[3]The Markovian requirements states that an optimal policy in a given state depends only on the state of the process in that stage and not on the state at proceeding stages. This requirement allows us to separate past decisions from current and future decisions when formulating and solving the DP model.

Chapter 2

PROVISIONS OF FOR AND REGULAR CCC LOAN PROGRAMS

The four most viable grain marketing and storage options currently available to a producer at the time of harvest are: (a) sell; (b) privately store the grain; (c) participate in the 1982 Farmer Owned Reserve program; or (d) participate in the 1982 CCC loan program. The option to sell at the time of harvest is available to all producers and under certain conditions may be the optimal decision. Selling at harvest saves the producer storage costs, but putting the grain into private storage gives the producer more flexibility. He is able to sell at a later date when the market price is usually higher or, if conditions dictate, the producer can go into either the FOR program or the regular CCC loan program. A producer pays for this increased flexibility by incurring storage costs for the grain.

The FOR program and the regular CCC loan program were continued by the Agriculture and Food Act of 1981. Operating regulations for the program are under the control of the Secretary of Agriculture. The FOR was instituted for wheat and rice in April 1977, and was later extended to other crops including corn. This policy, an outgrowth of debates and studies of the volatile behavior of the grain markets in the 1970s, is an attempt to stabilize grain markets. The provisions of these two federal programs for the 1982 crop will be presented as they pertain to the model developed in this study.

A major assumption of this study is that the producer has complied with the regulations of the Agriculture and Food Act of 1981, so the producer is eligible for these two federal programs. An outline of the essential compliance (eligibility) regulations follows.

1. To participate in the program for wheat, wheat acreage for 1982 crops must be reduced at least 15 percent from the established base.

2. To participate in the program for corn, corn acreage for 1982 crops must be reduced at least 10 percent from the established base.

3. The farm program acreage base for a particular crop will generally be the higher of (a) 1981 planted acreage; or (b) the average of 1980-81 planted acreages. For farms that have been following a definite crop rotation pattern, the established bases will reflect these variations.

4. Cross compliance is not required in 1982. A grain grower may participate in the program for one crop and not participate in the program for another crop.

5. When acreage is reduced in order to participate in the program, it is required that an equal amount of acreage be placed in a conserving use.

Nine month regular CCC loans and the three year FOR loans are available to eligible producers at a specified loan rate for the crop under contract. One similarity between these two programs is that producers retain ownership of the grain that is used as collateral for either loan. A second similarity is that any time between harvest and March 31 of the following year the producer can take out a regular loan or go into the FOR program.

An appealing feature of the regular CCC loan program is that the contract can be redeemed (loan + interest) without penalty at any time during the term of the loan. At maturity a producer may forfeit his loan, whereby CCC forgives both the principal and interest owed on the regular loan in exchange for the grain which was held as collateral, or the producer may retain ownership of the grain by paying principal plus interest. In the past a producer has been able to extend these nine month loans for twelve month periods, but no decision about extensions has been made for the 1982 crop. In the model developed for this study these regular loans were assumed to be extendable up to three years from harvest.

Another feature of the regular CCC loan program is that once the producer has taken out a nine month loan, he has the option of transferring the loan contract to a three year FOR contract if market price is below the set release price (Table 1). This transfer can only take place if the loan has not reached maturity or if the producer has received an extension on his loan. By transferring to the FOR program the producer will receive a premium loan (Table 1) plus storage payments. These two benefits make this an attractive alternative under certain conditions.

Table 1. Provisions of the 1982 regular CCC and FOR loan program for winter wheat and corn.

	Corn (National Average)	Winter Wheat (National Average)
	- - - - - $ per bushel	- - - - -
FOR loan price	2.90	3.92
FOR release price	3.25	4.65
Target price	2.70	4.05
FOR premium loan	.35	.45
FOR storage payments	.265	.265
Price Support (CCC loan price)	2.55	3.47

The interest rate charged for both the regular CCC loan program and the FOR program is the prevailing CCC interest rate, which is the rate at which it costs the Treasury to borrow money. This rate changes the first of every month. The interest rate charged on a particular loan contract (regular or FOR) is the rate that was prevailing at the time of the transaction. This rate remains in effect from the time of the transaction to December 31 of that same year. An annual rate change occurs on January 1. This new rate is applied to the remainder of the term of the loan contract. To simplify this study it was assumed that the interest rate remained constant throughout the three years of the study period. Since March 1978, interest on FOR loans has been waived after the first year of the three year contract. Another simplifying assumption used in this study is that interest is paid throughout the three year contract; that is, no interest payments are waived.

The FOR program has some added benefits that the regular loan program does not have. One such benefit is that the loan rate (support price plus premium loan) for FOR (Table 1) is greater than the loan rate (support price) for the regular loan program (Table 1). A second benefit is the storage payments received under the FOR program, which are slightly less than the cost of commercial storage. Another benefit as stated earlier is the waiver of interest payments after the first year of the contract.

For these added benefits the producer faces a major constraint. This constraint regulates the redemption of the reserve grain contract.

Voluntary redemption for a FOR contract before maturity is permitted without penalty only after the market price has reached or exceeded a specified release price (Table 1). If a producer redeems his FOR contract before maturity and the market price is at or above the release price the producer pays loan principal plus interest (if applicable). On the other hand, a penalty is assessed if the producer redeems the FOR contract when market price is below the release price. The penalty (liquidation damages) for redemption of the contract is given by the formula:

(contract + liquidation damages) = (principal of loan) + (interest rate) x (principal of loan) + (storage payments received) + (interest rate) x (storage payments) + (50% of interest rate) + (principal of loan).

Another aspect of the FOR program is that if the market price is above the release price, the producer does not have to redeem the contract. However, after two consecutive months of market price being above the release price, storage payments will stop. The storage payments will begin again once market price goes below the release price. The release price also regulates whether a producer can enter the FOR program. If market price is greater than or equal to the release price, a producer cannot take out a FOR loan.

Upon maturity of the FOR contract, redemption is much like that of the regular loan program. A producer may redeem the contract and pay principal plus interest (if applicable). The second option is to forfeit the contract whereby CCC forgives both the principal and interest owed in exchange for the grain.

To summarize, the producer foregoes the options of taking out a FOR contract or a regular CCC loan contract if he sells at harvest, but at the same time he does not pay any interest. Going into private storage at harvest gives a producer more alternatives (sell at a later date, FOR, or regular CCC loan program) on how and when he will market his grain. The regular loan and FOR contracts give interim financing to the participant so that the grain does not have to be sold at harvest time when market prices are usually lower. Regular CCC loan contracts have no constraints on redemption. The FOR program has redemption constraints, but the participant receives storage payments and a premium loan. Both the regular CCC loan and the FOR programs eliminate down side risk. The regular loan program does not sacrifice on the upside due to its redemption failures, except for interest payments. However, the FOR program sacrifices some upside potential when market price is between the loan price and release price. A participant can not redeem the contract in this market price range without substantial penalty.

Chapter 3

METHODOLOGY

Formulation of the DP Model

Successful application of the DP technique to a multiperiod optimization problem depends on appropriate specification of stages, state variables, decision alternatives and the Markovian relationship between state variables for each decision alternative at different stages (Nemhauser (1966); Bellman (1957)). With DP, as with other optimization techniques, one must balance the realism of model specification against cost of solving the model. A discussion of the compromises made for the grain storage-marketing problem follows.

Stages and States

In order to be cast in a DP framework a multiperiod process must be divided into time intervals or stages, with a decision being made at each stage. Stages for the stochastic DP model developed in this study are the day of harvest and each month thereafter for three years. Using months as stages gives a marketing interval that allows for seasonal fluctuations in prices, but is not so short that it gives an excessive number of stages and an unwieldy decision rule.

At each stage of the process, state variables are used to describe the state of the process. State variables used to describe the optimization problem at hand are of two types. The first type of state variable measures the market price for grain. Price is used as a state variable because the market price that a producer receives for his grain is a major determinant of the profit from marketing grain. Market price is treated stochastically in the model. Future cash market prices are not known with certainty; thus treating price stochastically makes the model more realistic. The second type of state variable indicates the type of program under which the grain is currently held. Stock states were defined as:

1) grain held in the FOR program,
2) grain held in a regular CCC loan program,
3) grain held in private storage without a loan, and
4) no grain in storage; the grain has already been sold.

Other variables, such as the date grain went into the FOR, were not specified as state variables because they would signfiicantly increase computational cost. Moreover, such variables would not likely have an appreciable impact on the decision rule.

Decision Alternatives

The decision made at a given stage deterministically or probabilistically controls the state in which the process will be found in the next stage. Decision alternatives considered in the model are:

0) Keep grain in the current stock state;
1) sell the grain;
2) With grain in the regular CCC loan program go into FOR program;
3) with grain in storage without a loan, obtain a regular CCC loan; and
4) with grain in storage without a loan, go into the FOR program.

Stock state transitions are deterministic; that is, once a decision is made at a particular stage the stock state at the next stage is known with certainty given a decision. However, price state transitions are stochastic, but the decision made at a particular stage has no effect on the price state at the next stage. The price state transition is a function of the values of current and past prices and the month of the year.

Recursive Equation

The objective function for the dynamic programming model is maximization of expected net present value of returns from one bushel of grain, given the various alternatives available at harvest. Consider now the DP recursive equation which provides the foundation for solving a multiperiod optimization problem with the DP technique.

A recursive equation must possess the following three properties. First, at any stage t a decision is to be made. Second, a decision together with the state of the process at stage t stochastically determines the state of the process at the next stage. Third, for any stage t, the state and the decision determine expected returns for that stage. Fourth, the process must be fully described at any stage t by the state at stage t. State variables in any other stage do not help describe the state at stage t.

The DP principle of optimality is the fundamental concept which provides the basis for the formulation of a recursive equation and for the solution technique. This principle states that an optimal policy has the property that whatever the initial state and decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the initial decision. An optimal policy is defined as the sequence of decisions that optimizes the objective function.

Application of the principle of optimality to the grain marketing problem gives the following recursive relationship for both winter wheat and corn:

$$V_t (S_t, PS_t) = \max_{D_t} [\pi_t(S_t, PI_t, D_t) + \beta EV_{t+1}(S_{t+1}, PI_{t+1})]$$

where

t = time (months since harvest);

$V_t (S_t, PI_t)$ = return from following an optimal policy from the current time period t through the final time period t_j;

PI_t = price information vector at time t;

Max = maximization operator;

D_t = decision made at time t;

π_t = expected immediate returns which depends on the stock state, price state, and the decision;

E = expectation operator; and

β = discount factor.

Using this recursive equation, the solution procedure moves backwards stage by stage, finding an optimal policy for each state at every stage. Due to the provisions of the Agriculture and Food Act of 1981, which make different decision alternatives applicable at some stages than at other stages, the stages of the DP model were divided into four subsets based on time intervals. The first time interval is the last stage ($V_T(S_T,PI_T)$), at which the regular CCC or FOR contracts are assumed to come due. In this stage, the highest value of the two different ways in which the regular CCC loans or FOR loans can be redeemed is calculated. The two alternative ways of redeeming contracts are: (a) sell the grain and pay back the loan; or (b) forfeit the contract and transfer ownership of the grain to the CCC. If the grain is in private storage without a loan, the terminal value is market price minus storage cost for that month.

In the second time interval, the recursive equation is solved for the next-to-last stage, (T-1), through time period 7 where decision alternative 3 (in private storage -- obtain a regular CCC loan) and alternative 4 (in private storage -- go into FOR program) are not available to the producer. The provisions of the regular loan program do not allow a producer to take out a regular CCC loan on his crop after March 31 (assumed to be six months after harvest). The producer cannot go into the FOR program after March 31, unless prior to March 31 the producer took out a regular CCC loan on the crop.

In the third and fourth time intervals of the DP model, all of the decision alternatives are viable options for the producer. The recursive equation for time periods six through one are solved in the third time interval, and returns for the day of harvest are calculated in the fourth interval, thus completing the solution process.

If the decision D_t is to sell at time t, the value of $V_t(S_t,PI_t)$

is $\pi_t(S_t, PI_t, D_t)$ and the producer has no future returns $V_{t+1}(S_{t+1}, PI_{t+1}) = 0$. Any decision, except sell at time t, gives a positive value of $V_{t+1}(S_{t+1}, PI_{t+1})$. This value is dependent on the stock state and the price information vector. The decision D_t and stock state S_t at time t determine the stock state S_{t+1} at time t+1. PI_{t+1} is probabilistically dependent on PI_t and the month of the year. The price information vector PI_t is independent of the decision alternatives.

The major difference between the winter wheat and the corn recursive equation is in the market price information vector (PI_t). For winter wheat this vector contains only current price. Current market price is used to find the value of a bushel of winter wheat if it is sold. This price is also used to generate first order Markovian transition probabilities, which are probabilities of prices next month given the current price.

The price information vector for corn contains two values, current market price and price lagged one month. The current price gives the value of a bushel of corn if sold. Both current and lagged prices are used to generate second order Markovian transition probabilities for price the next period.

Estimation of the Price Forecasting Equations

Two time-series models, one for corn and one for winter wheat, were estimated for the purpose of probabilistically predicting future values of market prices. The price forecasting equations were used to generate Markovian transition probabilities (see Appendix A), which give the probabilities of price next month given previous prices.

Price forecasting equations must be kept simple in terms of the number of variables in the equation in order to keep the DP model computationally manageable. Any variable in the equation except time must become a state variable in the DP model. Two reasons for this needed simplicity are the curse of dimensionaltiy and any variable in the equation other than lagged price, such as stockpile of U.S. grain, must have its own transition probabilities computed. In theory a DP model is able to incorporate any number of state variables, but in practical applications this is not possible from a computational standpoint.[4]

If a variable other than lagged prices is added to the equation, the problem of computing transition probabilities for this nonprice variable is encountered. Calculation of these nonprice variable transition probabilities would complicate the DP model, yet it was deemed that they would not significantly improve the accuracy of the decision rule.

Using the above information, it was assumed that market price could be forecast by a time series model using lagged prices and

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[4]The curse of dimensionality affects both the number of computations and computer storage requirements. As the total number of states increase, the computational and storage requirements increase rapidly since a value for every possible state combination must be calculated and stored. The increase in storage requirements and cost, due to the increase in the number of states, is the curse of dimensionality; thus the number of states must be kept reasonably small.

monthly variations

$$P_t = f(P_{t-1}, P_{t-2}, \ldots, P_{t-s}, \text{ monthly variation})e^{\mu t}$$

where,

P_t = market price at time t; and

μ_t = error term.

As with any time-series model, this equation does not give a structural explanation for changes in market price. However, this model does replicate past market price behavior in such a way that it will help forecast future behavior of price, unless the structure of the market changes.

One would expect grain prices to have relatively higher variability when the market price is high. A multiplicative error term better accounts for this higher variability at high prices than an additive error term. When estimating this equation it is desirable to smooth the monthly variations. For corn this smoothing was accomplished by polynomial constraints on twelve monthly dummies. Winter wheat monthly variations were postulated to follow a sine function, which symmetrically smooths the variations. The monthly dummies for corn and the monthly variation (sine function) for winter wheat tell us nothing about what is causing the variations in market prices. However, they do give a quantitative measure of monthly variations that influence transition probabilities.

Although economic and statistical theory tells us that a time-series model can be constructed using past values of a variable, it does not tell us the functional form of the equation. The specification of an equation can take two forms: linear or nonlinear in parameters. Statistical results for both specifications are presented in Table 2. To compare adjusted R^2 and standard error of the estimates between two equations, the dependent variables must be in the same form. Since the dependent variables of the linear and nonlinear equation used here are not in the same form, a measure of relative dispersion is needed to compare the forms. When an equation is estimated in natural units, the coefficient of variation gives a measure of relative dispersion. For an equation that is estimated in log form, the standard error of the estimate is a measure of relative dispersion. By comparing the appropriate values in Table 2, it can be seen that the nonlinear forms have smaller relative dispersion. This method of comparing relative dispersion is a practical method, but in no way is it fool proof.[5]

The nonlinear form was used to develop the transition probabilities. Two reasons for this decision are 1) the smaller relative dispersion, and 2) the nonlinear form made it easier to handle the multiplicative error term. As stated earlier this type of error structure helps in overcoming the differing variability in prices when market price is either high or low. During the Russian wheat deal period, heteroscedasticity in the error term was prevalent when using an additive error term; a multiplicative error term helped overcome this heteroscedasticity problem.

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[5]Personal communication with Dr. Oscar R. Burt.

Table 2. Regression results for various formulations of the price forecasting equation.

Winter Wheat

Model[e]	Estimated coefficient (t-ratio in parenthesis) α_1	α_2	α_3	α_4	α_5	α_6	Selected Statistics MD[a]	$\bar{R}^2$	SEE[b]	CV[c]	D-W[d]
A	1.1473 (12.75)	-.20537 (-2.30)	.88913 (1.64)	-	-	-	None	.9230	.5284	.1108	2.0770
B	.96224 (44.85)	-	.20607 (2.51)	-	-	-	5th	.9403	.0810	-	1.631
B	1.1751 (14.03)	-.21806 (2.62)	-.18864 (2.50)	-	-	-	2nd	.0454	.0775	-	2.011
C	.9431 (55.08)	-	.5361 (8.46)	1.0798 (39.77)	.06045 (1.98)	-3.79581 (7.50)	-	.9600	.0642	-	-

Corn

Model[e]	Estimated coefficient (t-ratio in parenthesis) α_1	α_2	α_3	α_4	α_5	α_6	Selected Statistics MD[a]	$\bar{R}^2$	SEE[b]	CV[c]	D-W[d]
A	1.3009 (15.80)	-.33387 (4.04)	$-.07\times10^{-8}$ (2.74)	-	-	-	5th	.9491	.2464	.0605	1.458
B	.98123 (46.109)	-	-	-	-	-	5th	.9426	.0602		1.253
B	1.3540 (16.24)	-.38633 (4.60)	-	-	-	-	5th	.9506	.0559		1.971
C	1.2950 (14.83)	-.32960 (3.77)	.11726 (2.04)	-	-	-	5th	.9512	.0552		1.965

[a]The degree of the polynomial constraint put on MD.

[b]Standard error of the estimate

[c]Coefficient of variation

[d]Durbin Watson's statistic is not very powerful when have lagged dependent variables on the right hand side of the equation.

[e]

Model	Equation
A	$P_t = \alpha_1 P_{t-1} + \alpha_2 P_{t-2} + \alpha_3 RT + MD + u_t$
B	$P_t = P_{t-1}^{\alpha_1} \; P_{t-2}^{\alpha_2} \; e^{\alpha_3 RT} \; MD e^{u_t}$
C	$P_t = [\alpha_4 P_{t-1}^{a_1} \; e^{\alpha_3 RT} + \alpha_5 \sin(\alpha_6 + .523599\ (T))] \; e^{u_t}$

Where,

P_t = market price at time t,

u_t = error term at time t,

MD = seasonal term smoothed by polynomial constraints ($MD = e^{\text{polynomial 10}}$ where D = 12 monthly dummy variables),

RT = $1/(t/31)^2$ (T = t,2,...,134, numbers the months of data with T = 1 being No. 1970) is a dummy variable to handle the Russian Wheat Deal.

Wheat Equation

Winter wheat market price was postulated to follow a sine function in its yearly cycle. Winter wheat appears to follow this symmetric type of cycle because of the length of the harvest period. Harvest starts in southern U.S. during the spring and proceeds northward through summer and fall. Also affecting wheat prices is the harvest period in the Southerm Hemisphere, which would tend to smooth out the world supply of wheat and thus world price.

The wheat equation used in this study is of the following form:

$$P_t = [\alpha_1 P_{t-1}^{\alpha 2} e^{\alpha_3 RT} + \alpha_4 \mathrm{Sin}(\alpha_5 + .523599(T))]e^{\mu t}$$

where,

$RT = 1/(T-31)^2$ if $T \geq 32$; $T = 1, 2, \ldots, 139$

$RT = 0$ if $T < 32$;

and μ_t = error term at time t.[6]

RT is a dummy variable used to account for the jump in prices that occurred because of the Russian Wheat Deal. The form $1/(T-31)^2$ gives a positive series for values of this dummy variable. For $T = 32$ the month in which market price first jumped, the dummy variable is equal to 1. This value allows RT to account for the jump in prices. Lagged prices, after $T = 32$, are able to account for the higher level of prices following the deal. Because of lagged prices

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[6] $T = 1,2,\ldots,134$ is a variable used to number the months of data, where $T = 1$ is Nov. 1970.

accounting for the higher level and market adjustment, RT should decline rapidly toward zero. This positive series allows a rapid decline.

The number, .523599, in the equation forces the sine function to cycle every twelve months.[7] The sine function and related parameters are used to account for monthly variation in price.

As a justification of the sine function, the wheat equation was estimated using monthly dummies.

$$P_t = [P_{t-1} e^{RT\alpha_2} MD] e^{\mu_t}$$

where

MD is seasonal terms smoothed by polynomial constraints.

Monthly equilibrium prices from this equation and the sine function equation were calculated using an iterative procedure; these monthly equilibrium prices are plotted in Figure 1. The sine function was picked over the monthly dummy model for two reasons: 1) the sine function smoothed December to January better and 2) the sine function gave a smaller coefficient of variation for the regression residuals.

The equation using the sine function was estimated using price lagged once and twice. The asymptotic t-ratio for price lagged twice (P_{t-2}) was approximately two, which is not highly signficant. Since the second order price term was not highly significant, the equation with price lagged only once was chosen to reduce the number of state

[7]The sine function cycles every 2Π in radians: $2\Pi/12$ = .1523599.

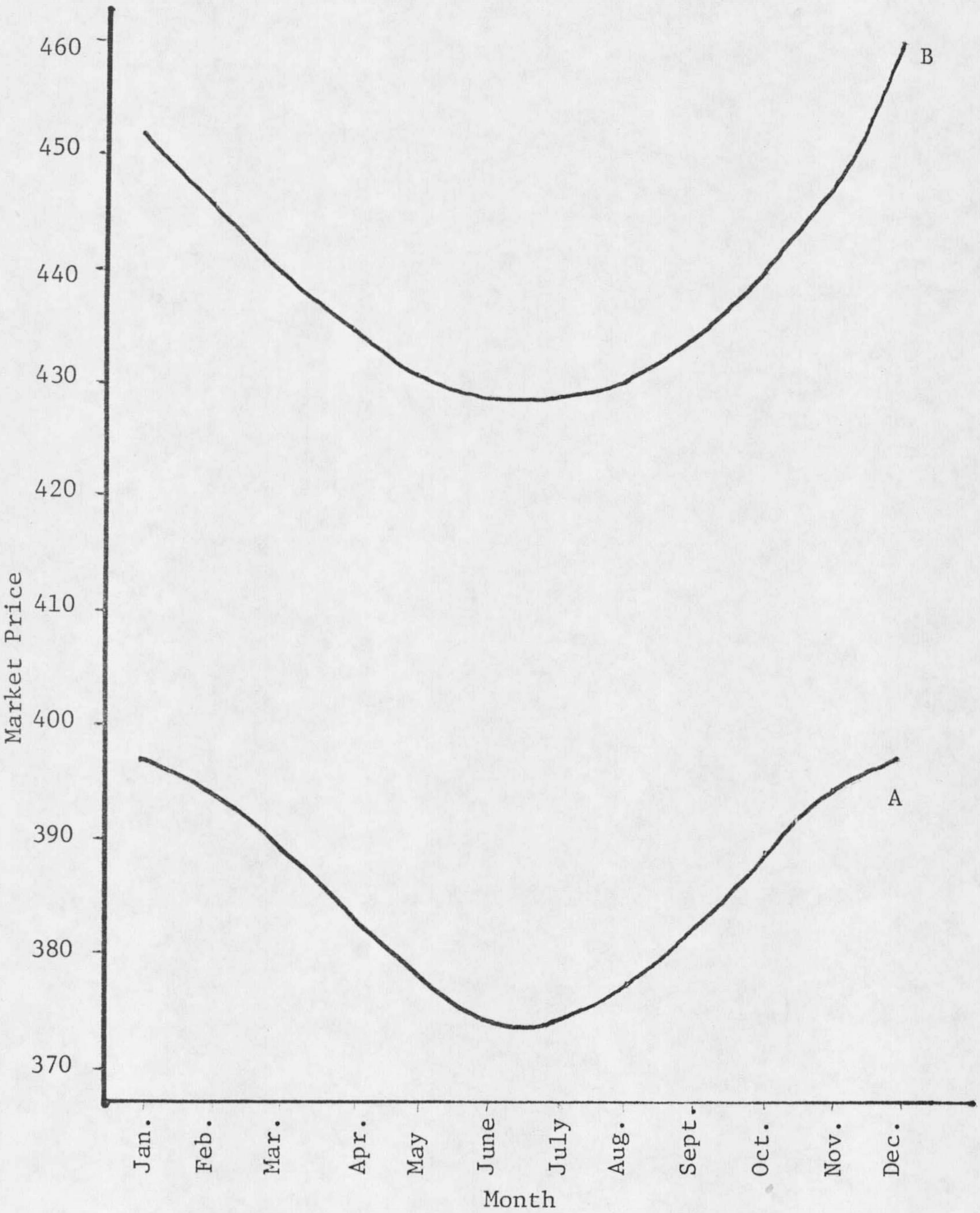

Figure 1. Implied equilibrium for winter wheat.

Curve A: $P_t - 1.0798\ P_{t-1}^{.04311} + .0604470\ \mathrm{Sin}\ (-3.795813 + .523599{*}M)$

Curve B: $P_t = P_{t-1}^{.96164}\ MD$

variables in the DP model.

The wheat forecasting equation used to generate first order Markovian transition probabilities is

$$P_t = 1.079852\, P_{t-1}^{.9431098}\ \underset{(8.46)}{} + \underset{(1.98)}{.0604470} \sin (\underset{(7.50)}{-3.795813 + .52399{*}M})$$

where P_t = market price at time t;

M = 1, 2, ..., 12 months of the year with Jan. = 1;

$\bar{R}^2$ = .96;

Standard error of the estimate = .064222.

Asymptotic t-ratios are in parenthesis under the estimated coefficients. These values show that all the coefficients are highly significant except for one coefficient associated with the sine function. Although the coefficient that measures the height of the sine term is not highly significant (t = 1.98), it is highly correlated with the significant coefficient (t = 7.50) that locates the peak and valley of the sine term, suggesting that the sine expression is quite significant.

Corn Equation

Corn prices[8] were not postulated to follow a symmetric pattern over their yearly cycle. Since corn harvest occurs at approximately one time during the year, we can expect an asymmetrical seasonal price pattern. The form of the corn price forecasting equation was postulated to be

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[8]This is the price of #2 yellow corn at Chicago.

$$P_t = P_{t-1}^{\alpha_1} P_{t-2}^{\alpha_2} e^{\alpha_3 RT} \cdot MD \, e^{\mu t}$$

where

MD = seasonal terms smoothed by polynomial constraints;

RT = the dummy variable for the Russian wheat deal, it is the same as in the winter wheat equation; and

μ_t = the error term.

The equation was estimated in its log linear form

$$\log P_t = \alpha_1 \log P_{t-1} + \alpha_2 \log P_{t-2} - \log MD + \mu t.$$

The equation obtained from estimating this log-linear form was used to generate second order Markovian transition probabilities. The equation with its estimated coefficients is

$$P_t = P_{t-1(14.831)}^{1.2950} \quad P_{t-2(-3.767)}^{-.32960} \quad MD$$

$\bar{R}^2$ = .95177, Standard error of estimate = .055185

where MD = 1.031959 for January;

= 1.040398 for February;

= 1.056914 for March;

= 1.056914 for April;

= 1.057956 for May;

= 1.052607 for June;

= 1.042388 for July;

= 1.030358 for August;

= 1.021540 for September;

= 1.022592 for October;

= 1.042270 for November; and

= 1.0292796 for December.

The asymptotic t-ratios in parentheses under the coefficients show that prices lagged once and twice are significant.

Figure 2 shows the equilibrium corn prices that were obtained by using an iterative procedure on the above equation. By looking at these equilibrium prices it can easily be seen that corn prices do not follow a symmetrical pattern as was found for wheat prices. Due to these asymmetric equilibrium prices a normal sine function in the corn forecasting equation did not handle monthly variation satisfactorily.

The seasonal term ($MD = e^{\text{polynomial (D)}}$ where D = 12 monthly dummy variables) has a discrete jump between December of one year and January of the next. The above procedure can smooth the dummied from January through December, but unfortunately cannot smooth December to January. Procedures that can smooth December to January are unjustifiably complicated for this study. Even with this discrete jump between January and December, it should be noted that January and December equilibrium prices in Figure 2 are approximately the same. Polynomial of degrees two to eight were used in estimation of the equation. The results of the equation above were obtained by using a 5^{th} degree polynomial in the MD term. Using a 5^{th} degree polynomial gave the best statistical results (highest $\bar{R}^2$ and lowest standard error of the estimate).

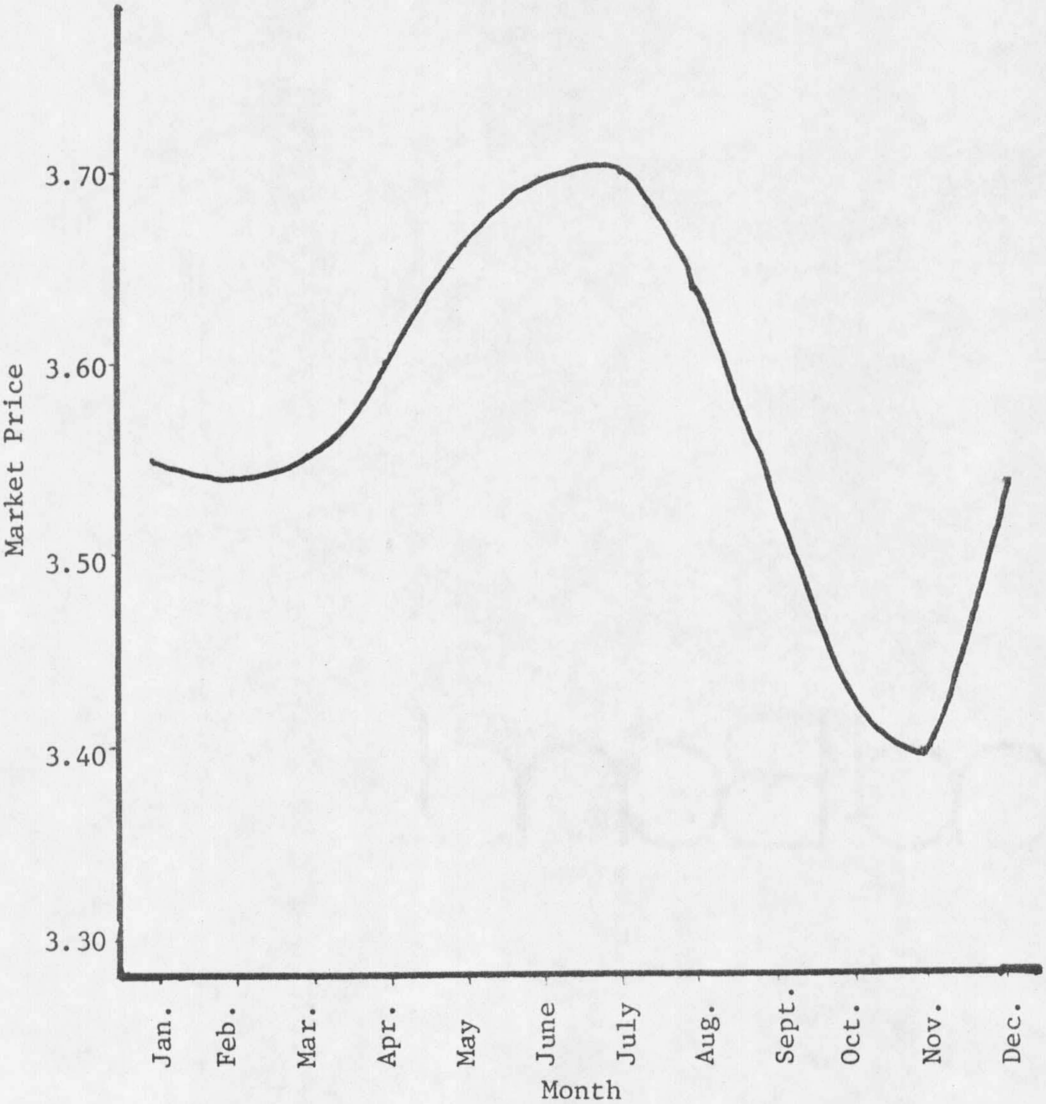

Figure 2. Implied equilibrium prices for corn

Equation: $P_t = P_{t-1}^{1.2950} \; P_{t-2}^{-.32960} \; MD$

Chapter 4

RESULTS

The major portion of this chapter is devoted to a discussion of the results of the DP models. After the results are presented the conditional and unconditional probabilities of being in the various stock states are discussed. Chapter five concludes with limitations of the study and recommendations for further study.

Assumptions

Before the results of the DP model are discussed, a summary of the assumptions made in developing the model will be stated. Some of these assumptions have been discussed elsewhere but are reprinted here for completeness.

1. Perhaps the most critical assumption is that the transition probabilities obtained from the historical time-series analysis are valid for the future.

2. The producer has complied with the regulations of the Agriculture and Food Act of 1981. The producer is eligible to go into either the FOR or the regular CCC loan program.

3. The regular CCC loans are extendable up to a period of three years from the time of harvest.

4. The interest rate on the loans stays constant throughout the period of the loan contract for both regular CCC and FOR loans.

5. The Secretary of Agriculture does not issue an emergency call price and the Secretary does not prevent participation in the FOR program by invoking a maximum quantity that can be put into the reserve.

6. Interest is paid throughout the three-year contract of the FOR. In other words, interest payments are not waived after the first year of the producer's FOR contract. If

this was not assumed, another state variable, which indicated when the producer went into the FOR, would have to be added to the DP model. This assumption may bias the results in the sense that if interest is waived after the first year, the FOR loan is more attractive than if interest is paid throughout the three-year contract term.

7. Liquidation damages, as discussed in Chapter Two, were set at an arbitrary high number that was large enough to prevent liquidation as an alternative in the model. This assumption was made to avoid adding the state variable when producer entered the FOR program to the DP model.

8. The deficiency payment part of the Agriculture and Food Act of 1981 is ignored in the DP model. It was assumed that the producer is eligible for the federal programs and anyone eligible for the programs will get these payments provided they have not sold their grain when and if these payments are made. No matter what program (whether CCC loan, FOR loan, or in storage) a producer who has complied with the regulations will receive these payments if enacted.

9. If the producer enters the FOR program any month after harvest, the FOR contract only runs until three years after the date of harvest and not for three years from the time the producer entered the FOR program. This assumption avoids adding another state variable to the DP model.

10. Storage payments in the DP model stop as soon as market price reaches or is above the release price, instead of two consecutive months of market price being at or above the release price. This assumption was made to avoid adding a state variable (when market price exceeded the release price) to the DP model.

11. The producer does not experience a cash flow constraint.

12. The producer is able to enter either the regular loan or FOR program for up to six months after harvest; that is March 31 is assumed to occur six months after harvest.

13. Loss of grain put in storage due to shrinkage and other factors is 1 percent over three years, with an equal percentage loss for each month the grain is in storage.

DP Solution

The DP models were solved for two scenarios. The difference betwen the two scenarios is the cost of storing grain. Two extremes were used. The first scenario had no cost for storing grain, while the second scenario used the cost of commercial storage ($.36/bu/yr) as the cost to the producer of storing grain. The first scenario assumes the producer owns the storage bins and has no opportunity cost for use of the bins. The second scenario assumes that the producer does not own storage bins and must use commercial storage. Table 3 summarizes the important parameters for each scenario.

Table 3. Parameters for each scenario

	Winter Wheat		Corn	
Parameter	Scenario 1	Scenario 2	Scenario 1	Scenario 2
	annual			
Interest Rate (FOR and CCC loan)	13%	13%	13%	13%
Inflation Rate	7%	7%	7%	7%
Discount Rate	9%	9%	9%	9%
Cost of Storage	$0.00/bu	$.36/bu	$0.00/bu	$.36/bu
For storage payments	$.265/bu	$.265/bu	$.265/bu	$.265/bu
Loss of Grain[a]	1% over 3 years	1% over 3 years	1% over 3 years	1% over 3 years

[a]Loss of grain in storage is due to animals, shrinkage, loading and unloading. An equal percentage loss for each month the grain is in storage is assumed.

Market prices in the model are in real September 1982 dollars. The price states, each of which is a range of prices, were set up so they included the smallest and largest price in the time series data used to estimate the price forecasting equations.

Under both scenarios the optimal decision is dependent on the stock state, price state and stage. One must keep in mind that the decision rules are valid only to the extent that the transition probabilities are valid for three years into the future.

One other aspect of the DP model should be considered before the results are presented. This is the loss of grain due to shrinkage, insects, rodents, and loading and unloading the grain that occurs when storing grain. The model presented here assumes that a 1 percent loss occurs over three years, with an equal percentage loss for each month the grain is in storage.

Winter Wheat

Twenty price states (price intervals) were defined for winter wheat. The price states values range from \$2.50 to \$7.50/bu with 25¢ being the range for each price state.

Scenario 1: No storage costs. Table 4 summarizes the results under scenario one for the day of harvest. This table presents the present value of the different marketing alternatives if a producer follows an optimal policy from months 1 to 35, given the marketing decision in month 0 (day of harvest). These results tell us that a producer who wants to maximize expected profit and has no storage cost, should

Table 4. Winter wheat optimal decisions for the day of harvest with no storage cost.

Midpoint of Price State[a]	Optimal Decision at Harvest[b]	Expected Optimal Returns	Expected returns for different decisions at day of Harvest[c] Sell	FOR	Loan	Store
2.625	FOR	4.655	2.625	4.655	4.633	4.633
2.875	FOR	4.655	2.875	4.655	4.643	4.643
3.125	FOR	4.679	3.125	2.679	4.657	4.657
3.375	FOR	4.696	3.375	4.696	4.674	4.674
3.625	FOR	4.718	3.625	4.718	4.696	4.694
3.875	FOR	4.747	3.875	4.747	4.725	4.725
4.125	FOR	4.787	4.125	4.787	4.765	4.765
4.375	FOR	4.840	4.375	4.840	4.818	4.818
4.625	FOR	4.915	4.625	4.915	4.893	4.893
4.875	STORE	4.981	4.875	.00	4.976	4.981
5.125	STORE	5.145	5.125	.00	5.123	5.145
5.375	SELL	5.375	5.375	.00	5.328	5.364
5.625	SELL	5.625	5.625	.00	5.578	5.613
5.875	SELL	5.875	5.875	.00	5.828	5.863
6.125	SELL	6.125	6.125	.00	6.078	6.113
6.375	SELL	6.375	6.375	.00	6.328	6.363
6.625	SELL	6.625	6.625	.00	6.578	6.613
6.875	SELL	6.875	6.875	.00	6.828	6.863
7.125	SELL	7.125	7.125	.00	7.078	7.113
7.375	SELL	7.375	7.375	.00	7.327	7.363

[a] Price state range from $2.50 to $7.50 with $.25 being the interval for each price state range.

[b] Decisions: FOR - enter the FOR program
STORE - store w/o a federal loan
SELL - sell grain
LOAN - enter the regular CCC loan program

[c] Expected returns if at harvest choose one of these marketing alternatives (FOR, STORE, SELL, LOAN) and then follow an optimal policy for months 1-35.

enter the FOR program as long as market price is below the release price. Storage payments that a producer receives in the reserve program dominate the decision rule at low prices.

For two price states (4.76-5.00 and 5.01-5.25) the producer's optimal decision is to privately store the grain. Storing the grain gives the producer the options of entering the reserve program if market price drops below the release price or selling the grain if the price rises. By storing the grain and not entering the regular CCC loan program the producer does not incur any interest charges. This decision may be altered if the assumption of no cash flow constraint was not imposed on the model. It should be noted that less than three cents separate the decisions to store the grain and sell for price state 5.01-5.25.

If market price at harvest is equal to or greater than $5.26/bu the decision which maximizes the expected present value of a bushel of winter wheat is to sell the grain. It should also be noted that the present values for the different marketing alternatives for price states greater than 5.25 given in Table 4 differ by less than six cents.

Table 5 gives the optimal decisions for months 1-6 under scenario one. During this period, all of the decision alternatives are viable options to a producer. This table reads as follows. The left hand column gives the month (1-6) of the process. The next column gives the stock state (1 = grain held in FOR program, 2 = grain held under the regular CCC loan contract, and 3 = grain in storage). The last

Table 5. Winter wheat optimal decisions[a] for months 1-6 with cost of storage = \$0.00/bu/yr.

Months since harvest	Stock State[b]	2.625	2.875	3.125	3.375	3.625	3.875	4.125	4.375	4.625	4.875	5.125	5.375	5.625	5.875	6.125	6.375	6.625	6.875	7.125	7.375
		Midpoint of each price state[c]																			
1	3	4	4	4	4	4	4	4	4	4	0	0	1	1	1	1	1	1	1	1	1
1	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
2	3	4	4	4	4	4	4	4	4	4	0	0	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
2	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
3	3	4	4	4	4	4	4	4	4	4	0	1	1	1	1	1	1	1	1	1	1
3	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
3	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
4	3	4	4	4	4	4	4	4	4	4	0	1	1	1	1	1	1	1	1	1	1
4	2	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1
4	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
5	3	4	4	4	4	4	4	4	4	4	1	1	1	1	1	1	1	1	1	1	1
5	2	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1
5	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
6	3	4	4	4	4	4	4	4	4	4	1	1	1	1	1	1	1	1	1	1	1
6	2	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1
6	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1

[a]Decisions - 0 - keep grain in Current Stock State.
1 - Sell the grain
2 - With grain in regular CCC loan program, for into FOR program.
3 - With grain in storage without a loan, obtain a regular CCC loan.
4 - With grain in storage without a loan, go into FOR program.

[b]Stock States - 1 - Grain in FOR program.
2 - Grain in regular CCC loan program.
3 - Grain in storage without a loan.

[c]Twenty price states were considered. Each price state was at 25¢ interval.

twenty columns of the table give the optimal decision for a particular stage, stock state and price state. Each of the twenty columns is a separate price state; the first column is price state \$2.51-2.75, second \$2.76-3.00, and so forth up to the twentieth column, which is price state \$7.26-7.50. As an example of how to read this type of table, consider month 5, stock stage 3 and price state \$5.01-5.25 (the eleventh column of the twenty price state columns). For this situation, the decision is 1 which is to sell the grain.

The optimal decisions for months 1-6 are very similar to the decision rule for the day of harvest. If the producer is not in the FOR program (stock state 2 or 3) and market price is below the release price, the optimal decision is to enter the FOR program. If the producer is in stock state 1 (grain held in FOR program) he should remain in this stock stage when price is less than \$4.76/bu. As in month 0 (day of harvest) a producer should sell his winter wheat whenever market price is equal to or greater than \$5.26. For the two price states \$4.76-5.00 and \$5.01-5.25 the optimal decision varies according to the time, stock state and price state.

The optimal decision for months 7-35 for winter wheat under scenario 1 are given in Table 6. During these stages, decisions 3 (in private storage go into regular CCC loan program) and 4 (in private storage go into FOR program) are not available to the producer. The following two conclusions can be drawn: 1) if the producer is in a regular CCC loan program and price is below the release price, the producer should enter the FOR program; and 2) when price is equal

Table 6. Winter wheat optimal decision for months 7-35 with cost of storage = $0.00/bu/yr.

Months since Harvest	Stock State	Midpoint of each price state																			
		2.625	2.875	3.125	3.375	3.625	3.875	4.125	4.375	4.625	4.875	5.125	5.375	5.625	5.875	6.125	6.375	6.625	6.875	7.125	7.375
7	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
7	2	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1
7	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
8	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
8	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
8	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
9	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
9	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
9	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
10	3	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
10	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
10	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
11	3	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
11	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
11	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
12	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
12	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
12	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
13	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
13	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
13	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
14	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
14	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
14	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
15	3	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
15	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
15	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
16	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
16	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
16	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
17	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
17	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
17	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
18	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
18	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
18	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
19	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
19	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
19	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
20	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
20	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
20	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
21	3	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
21	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
21	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
22	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
22	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
22	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
23	3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
23	2	2	2	2	2	2	2	2	2	2	0	0	0	0	1	1	1	1	1	1	1
23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
24	3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
24	2	2	2	2	2	2	2	2	2	2	0	0	0	0	1	1	1	1	1	1	1
24	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
25	3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
25	2	2	2	2	2	2	2	2	2	2	0	0	0	0	1	1	1	1	1	1	1
25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
26	3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
26	2	2	2	2	2	2	2	2	2	2	0	0	0	0	1	1	1	1	1	1	1
26	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
27	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
27	2	2	2	2	2	2	2	2	2	2	0	0	0	0	1	1	1	1	1	1	1
27	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
28	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
28	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
28	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
29	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
29	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
29	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
30	3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
31	3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
31	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
31	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
32	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
32	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
32	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
33	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
33	2	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1
33	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
34	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
34	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
34	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
35	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
35	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
35	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1

For an explanation of this table, see the footnote to Table 5.

to or greater than $5.76 the optimal decision for any stock state and month is to sell. The rest of the optimal decisions vary, depending on the stock state, price state and month, with months giving a seasonality effect on when to sell.

Scenario 2: Storage Cost. The optimal decisions for winter wheat under scenario two differ from the decisions under scenario one. Under scenario two the cost of storage is assumed to be $.36/bu/yr which is approximately the cost of commercial storage. This storage cost is greater than the storage payments made under the FOR program ($.265/bu/yr). With high storage cost, it is clearly less profitable to a producer to store grain than when the producer has no variable storage costs. The optimal decisions under scenario two reflect the lower profitability in storing grain. The two decision alternatives of going into the CCC loan program and storing the grain without a loan are never the optimal decisions for any month.

For winter wheat, the optimal decisions with storage costs for the day of harvest are presented in Table 7. This table also gives the expected returns from following an optimal policy given the decision alternative at the day of harvest. The decision rule for the day of harvest under scenario two is simple. When market price is less than $4.25/bu go into the FOR program and when price is greater than $4.25/bu the optimal decision is to sell. Going into the reserve gives the producer the opportunity to sell after harvest when price is usually higher, while also receiving storage payment that cover most of the cost of storage.

Table 7. Winter wheat optimal decision for the day of harvest with cost of storage = \$.36/bu/yr.

Midpoint of Price State	Optimal decision at Harvest	Expected Optimal Returns	Expected returns for different decisions at day of Harvest			
			Sell	FOR	Loan	Store
2.625	FOR	3.771	2.625	3.771	3.749	3.749
2.875	FOR	3.801	2.875	3.801	3.779	3.779
3.125	FOR	3.844	3.125	3.844	3.822	3.822
3.375	FOR	3.900	3.375	3.900	3.878	3.878
3.625	FOR	3.976	3.625	3.976	3.953	3.953
3.875	FOR	4.076	3.875	4.076	4.054	4.054
4.125	FOR	4.207	4.125	4.207	4.185	4.185
4.375	SELL	4.375	4.375	4.373	4.351	4.358
4.625	SELL	4.625	4.625	4.571	4.549	4.584
4.875	SELL	4.875	4.875	.00	4.798	4.834
5.125	SELL	5.125	5.125	.00	5.048	5.084
5.375	SELL	5.375	5.375	.00	5.298	5.334
5.625	SELL	5.625	5.625	.00	5.548	5.583
5.875	SELL	5.875	5.875	.00	5.798	5.833
6.125	SELL	6.125	6.125	.00	6.048	6.083
6.375	SELL	6.375	6.375	.00	6.298	6.333
6.625	SELL	6.625	6.625	.00	6.548	6.583
6.875	SELL	6.875	6.875	.00	6.798	6.833
7.125	SELL	7.125	7.125	.00	7.048	7.083
7.375	SELL	7.375	7.375	.00	7.297	7.333

For an explanation of this table, see footnotes to Table 4.

The winter wheat decision rules for months 1 - 6 under scenario two are given in Table 8. Four conclusions that can be reached concerning the optimal decisions are: 1) if market price is equal to or greater than \$4.76, the optimal decision is to sell irrespective of the stock state and month; 2) if grain is in storage without a loan and price is less than \$3.75, the producer should take out a FOR contract; 3) if grain is in a regular CCC loan program and price is less than \$4.50, the producer should go into the FOR program; and

Table 8. Winter wheat optimal decisions for stages 1-6 with cost of storage \$.36/bu/yr.

		Midpoint of each price state																			
Months Months since Harvest	Stock State	2.625	2.875	3.125	3.375	3.625	3.875	4.125	4.375	4.625	4.875	5.125	5.375	5.635	5.875	6.125	6.375	6.625	6.875	7.125	7.375
1	3	4	4	4	4	4	4	4	0	1	1	1	1	1	1	1	1	1	1	1	1
1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
2	3	4	4	4	4	4	4	0	0	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
2	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
3	3	4	4	4	4	4	4	0	1	1	1	1	1	1	1	1	1	1	1	1	1
3	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1	1	1
3	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
4	3	4	4	4	4	4	4	0	1	1	1	1	1	1	1	1	1	1	1	1	1
4	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
5	3	4	4	4	4	4	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
6	3	4	4	4	4	4	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1

For an explanation of this table, see the footnotes to Table 5.

4) if the producer is in the FOR program he should stay in the program if market price is less than the release price and sell if market price equals or exceeds the release price.

Table 9 presents the optimal decisions for months 7 - 35 under scenario two. Two generalities that are independent of the month can be seen. First, a producer in any stock state should sell whenever price is equal to or exceeds $5.51. Second, if in stock state 2 and price is less than $4.25, a producer should enter the FOR program.

Corn

The decision rule for corn depends on two price state variables (current price and price lagged one month), the stock state, and the month since harvest. Ten price state values were considered for each price variable. These price state values run from $1.75 to $7.05 with 53¢ being the range for each price state value.

Tables 10 and 11 give the optimal decision for both scenarios (no cost of storage and storage cost of $.36/bu/yr) at the time of harvest. When current market price is greater than $3.34/bu and lagged price is equal to or greater than $3.87/bu the producer's optimal decision is to sell his crop at harvest under scenarios one and two. Another similarity between the two scenarios is that whenever current market price is between $6.52 and $7.05, the optimal decision is to sell. The decision to sell whenever current price is in this price state range ($6.52-$7.05) holds for all months and all stock states. Since this is the highest price range considered in

Table 9. Winter Wheat optimal decisions for months 7-35 with cost of storage - $.36/bu/yr.

Months since Harvest	Stock state	2.625	2.875	3.125	3.375	3.625	3.875	4.125	4.375	4.625	4.875	5.125	5.375	5.625	5.875	6.125	6.375	6.625	6.875	7.125	7.375
		Midpoint of each price state																			
7	3	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
7	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
8	3	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
8	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
9	3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
9	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
10	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
10	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
10	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
11	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
11	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
11	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
12	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
12	2	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1
12	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
13	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
13	2	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1
13	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
14	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
14	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1	1
14	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
15	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
15	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1	1
15	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
16	3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1	1
16	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
17	3	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1	1
17	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
18	3	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
18	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
19	3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
19	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
20	3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
20	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
21	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
21	2	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1
21	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
22	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
22	2	2	2	2	2	2	2	2	2	2	0	1	1	1	1	1	1	1	1	1	1
22	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
23	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
23	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
23	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
24	3	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
24	2	2	2	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1	1	1	1
24	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
25	3	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
25	2	2	2	2	2	2	2	2	2	0	0	0	0	1	1	1	1	1	1	1	1
25	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
26	3	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
26	2	2	2	2	2	2	2	2	2	0	0	0	0	1	1	1	1	1	1	1	1
26	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
27	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
27	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
27	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
28	3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
28	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
29	3	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
29	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
29	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
30	3	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
30	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
31	3	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
31	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
31	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
32	3	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
32	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
32	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
33	3	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
33	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
33	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
34	3	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
34	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
34	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
35	3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
35	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1	1	1	1	1	1	1
35	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1

For an explanation of this table, see the footnotes to Table 5.

Table 10. Corn optimal decisions for the day of harvest with cost of storage = $0.00/bu/yr.

		Midpoint of price state lagged one month[b]									
		2.015	2.545	3.075	3.605	4.135	4.665	5.195	5.725	6.255	6.785
Midpoint of current price state	2.015	FOR[a]	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR
	2.545	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR
	3.075	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR
	3.605	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
	4.135	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
	4.665	STORE	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
	5.195	STORE	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
	5.725	STORE	STORE	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL
	6.255	STORE	STORE	STORE	STORE	SELL	SELL	SELL	SELL	SELL	SELL
	6.785	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL

[a]FOR - enter FOR program; STORE - store without federal loan; LOAN - take out a regular CCC loan; SELL - sell.

[b]The range for each price state range is fifty three cents.

Table 11. Corn optimal decisions for the day of harvest with cost of storage = $.36/bu/yr.

Midpoint of current price state	Midpoint of price state lagged one month: 2.015	2.545	3.075	3.605	4.135	4.665	5.195	5.725	6.255	6.785
2.015	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR
2.545	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR
3.075	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
3.605	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
4.135	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
4.665	STORE	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
5.195	STORE	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL
5.725	STORE	STORE	STORE	SELL	SELL	SELL	SELL	SELL	SELL	SELL
6.255	STORE	STORE	STORE	STORE	SELL	SELL	SELL	SELL	SELL	SELL
6.785	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL	SELL

the model, selling whenever price is in this price range will maximize the present value of a bushel of corn.

For any lagged price state value under scenario one (no cost of storage) the optimal decision is to enter the FOR program whenever current price is less than the release price. Table 10, which presents the results under scenario one for the day of harvest, contains a triangular block in which the optimal decision is to store the corn. This block occurs when lagged price is low and the current price is significantly greater than the lagged price. The low lagged price and a higher current price suggest that market price is rising. With the expectation of rising price, the decision to store and sell later when expected price has stabilized is the optimal decision when maximizing expected profit.

The optimal decisions for the day of harvest under scenario two (storage cost of \$.36/bu/yr) is similar to those of scenario one. One major difference is the value of the current price variable in which a producer should enter the FOR program. Under scenario two this value is lowered by one price state range (market price less than \$2.81 go into FOR instead of less than release price). Under this scenario the cost of storage is greater than the FOR storage payments. Due to this difference, the expected price increase needs to be large enough to recover the storage cost. Therefore, the producer will be better off if he sells at a lower price and not pay for storage. The other difference between optimal decisions for the two scenarios is in the triangular block of private storage decisions. Under scenario two this block is smaller. Again, this is due to the storage costs the producer must pay if he stores the crop.

Tables 12, 13, 14 and 15 present the optimal decision for months 1 - 35 for both scenarios. These tables read similar to the winter wheat tables that present the results of months 1 - 35. The left hand column gives the month of the process with the next column giving the stock state. The next 100 columns present the optimal decisions. the 100 columns are grouped into ten groups of ten. Each group of ten represents a current price state with the smallest on the left and moving to the largest on the right. Within each group of ten the lagged price states are represented. The ten columns in each group gives the ten lagged price values with the smallest on the left and moving to the largest on the right. As an example of how to read the tables, find month 5 and stock state 3 on Table 12 with a lagged price range of \$2.28-\$2.81 (column 2 of each group of 10) and current price range of \$5.46-\$5.99 (the 8th group of 10). The optimal decision read from column 82 is 0 (keep the grain in storage without a loan).

Some generalities can be seen for the optimal decisions for months 1 - 35 under scenario one (Tables 12 and 13). A producer's optimal decision is to take out a FOR loan whenever current price is less than the release price and the producer is eligible to go into the FOR program (stock states 2 - 3 for months 1 - 6 and stock stage 2 for months 7 - 35). A second generality is that in months 7 - 35 and stock state 3 (in storage without a loan) the optimal

Table 12. Corn optimal decision for stages 1-6 with cost of storage = $0.00/bu/yr.

Stage	Stock State	Optimal decisions for every price state combination
1	3	4444444444444444444444444444401111111101111111110011111111000111111110001111111000011111111111111
1	2	2222222222222222222222222222222011111111011111111100111111110001111111100011111110000111111111111111
1	1	0000000000000000000000000000000011111111011111111100111111110001111111100011111110000111111111111111
2	3	4444444444444444444444444444401111111101111111110011111111000111111110000111111100001111111111111111
2	2	2222222222222222222222222222201111111101111111110011111111000111111110000111111100001111111111111111
2	1	0000000000000000000000000000000100000000011111111100111111110001111111100001111111000011111111111111
3	3	4444444444444444444444444444401111111100111111111000111111110000111111100000111111000000111111111111
3	2	2222222222222222222222222222200100000000011111111100011111111000011111110000011111100000011111111111
3	1	0000000000000000000000000000000000000000001111111100011111111000011111110000011111100000011111111111
4	3	4444444444444444444444444444401111111101111111110011111111000111111110001111111000011111111111111
4	2	2222222222222222222222222222200000000000111111111001111111100011111111000111111100001111111111111111
4	1	0000000000000000000000000000000000000000111111111001111111100011111111000111111100001111111111111111
5	3	4444444444444444444444444444401111111101111111110011111111000111111110000111111100001111111111111111
5	2	2222222222222222222222222222200000000000111111111001111111100011111111000011111110000111111111111111
5	1	0000000000000000000000000000000000000000111111111001111111100011111111000011111110000111111111111111
6	3	4444444444444444444444444444401111111101111111110011111111000111111110000111111100000111111111111111
6	2	2222222222222222222222222222200000000000111111111001111111100011111111000011111110000011111111111111
6	1	0000000000000000000000000000000000000000111111111001111111100011111111000011111110000011111111111111

Stages - Months since harvest
Stock states - 1 - grain held in FOR program.
2 - grain in regular CCC loan program.
3 - grain in storage without a loan.
Decisions - 0 - keep grain in current stock state.
1 - sell the grain.
2 - with grain in the regular CCC loan program, go into the FOR program.
3 - with grain in storage without a loan, obtain a regular CCC loan.
4 - with grain in storage without a loan, go into the FOR program.

Ten price state variables, 1.76-2.28, 2.29-2.81, ..., 6.52-7.05 for each price state. With current price state variables grouped into groups of ten. The smallest - the left group of ten and the highest price state - the right group of ten. Within each group of ten the lagged price states are represented. The ten columns in each group gives the ten lagged price values with the smallest on the left and moving to the largest on the right.

Table 13. Corn optimal decision for stages 7-35 with cost of storage = $0.00/bu/yr.

Stage	Stock State	Optimal decision for each price state combination	
7	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100000111111111111111
7	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
7	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
8	3	11111111111111111111111111111101111111110011111111	00111111110001111111000011111100000111111111111111
8	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
8	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
9	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100000111111111111111
9	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
9	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
10	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100001111111111111111
10	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100001111111111111111
10	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100001111111111111111
11	3	11111111111111111111111111111111111111110111111111	00111111110001111111000111111100001111111111111111
11	2	22222222222222222222222222222200000000000011111111	00111111110001111111000111111100001111111111111111
11	1	00000000000000000000000000000000000000000011111111	00111111110001111111000111111100001111111111111111
12	3	11111111111111111111111111111111111111110111111111	00111111110001111111000111111100001111111111111111
12	2	22222222222222222222222222222200000000000011111111	00111111110001111111000111111100001111111111111111
12	1	00000000000000000000000000000000000000000011111111	00111111110001111111000111111100001111111111111111
13	3	11111111111111111111111111111111111111110111111111	00111111110001111111000111111100001111111111111111
13	2	22222222222222222222222222222200000000000011111111	00111111110001111111000111111100001111111111111111
13	1	00000000000000000000000000000000000000000011111111	00111111110001111111000111111100001111111111111111
14	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100001111111111111111
14	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100001111111111111111
14	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100001111111111111111
15	3	11111111111111111111111111111101111111110011111111	00011111110000111111000001111100000011111111111111
15	2	22222222222222222222222222222200000000000011111111	00011111110000111111000001111100000011111111111111
15	1	00000000000000000000000000000000000000000011111111	00011111110000111111000001111100000011111111111111
16	3	11111111111111111111111111111111111111110111111111	00111111110001111111000011111100001111111111111111
16	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100001111111111111111
16	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100001111111111111111
17	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100001111111111111111
17	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100001111111111111111
17	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100001111111111111111
18	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100000111111111111111
18	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
18	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
19	3	11111111111111111111111111111101111111110011111111	00111111110001111111000011111100000111111111111111
19	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
19	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
20	3	11111111111111111111111111111101111111110011111111	00111111110001111111000011111100000111111111111111
.20	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
20	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
21	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100000111111111111111
21	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
21	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
22	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100001111111111111111
22	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100001111111111111111
22	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100001111111111111111
23	3	11111111111111111111111111111111111111110111111111	00111111110001111111000111111100001111111111111111
23	2	22222222222222222222222222222200000000000011111111	00111111110001111111000111111100001111111111111111
23	1	00000000000000000000000000000000000000000011111111	00111111110001111111000111111100001111111111111111
24	3	11111111111111111111111111111111111111110111111111	00111111110001111111000111111100001111111111111111
24	2	22222222222222222222222222222200000000000011111111	00111111110001111111000111111100001111111111111111
24	1	00000000000000000000000000000000000000000011111111	00111111110001111111000111111100001111111111111111
25	3	11111111111111111111111111111111111111110111111111	00111111110001111111000111111100001111111111111111
25	2	22222222222222222222222222222200000000000011111111	00111111110001111111000111111100001111111111111111
25	1	00000000000000000000000000000000000000000011111111	00111111110001111111000111111100001111111111111111
26	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100000111111111111111
26	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
26	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
27	3	11111111111111111111111111111101111111110011111111	00011111110000111111000001111100000011111111111111
27	2	22222222222222222222222222222200000000000011111111	00011111110000111111000001111100000011111111111111
27	1	00000000000000000000000000000000000000000011111111	00011111110000111111000001111100000011111111111111
28	3	11111111111111111111111111111111111111110111111111	00111111110001111111000011111100001111111111111111
28	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100001111111111111111
28	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100001111111111111111
29	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100001111111111111111
29	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100001111111111111111
29	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100001111111111111111
30	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100000111111111111111
30	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
30	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
31	3	11111111111111111111111111111101111111110011111111	00111111110001111111000011111100000111111111111111
31	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
31	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
32	3	11111111111111111111111111111101111111110011111111	00111111110001111111000011111100000111111111111111
32	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
32	1	00000000000000000000000000000000000000000011111111	00111111110001111111000011111100000111111111111111
33	3	11111111111111111111111111111101111111110011111111	00111111110001111111000011111100000111111111111111
33	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
33	1	00000000000000000000000000000000000000000011110000	00111111110001111111000011111100000111111111111111
34	3	11111111111111111111111111111101111111110111111111	00111111110001111111000011111100000111111111111111
34	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100000111111111111111
34	1	00000000000000000000000000000000000000000000000000	00111111110001111111000011111100000111111111111111
35	3	11111111111111111111111111111111111111110111111111	00111111110001111111000011111100001111111111111111
35	2	22222222222222222222222222222200000000000011111111	00111111110001111111000011111100001111111111111111
35	1	00000000000000000000000000000000000000000000000000	00111111110001111111000011111100001111111111111111

See Table 12 for explanation.

Table 14. Corn optimal decision for stages 1-6 with cost of storage = $.36/bu/yr.

Stage	Stock State	Optimal decision each price state combination
1	3	4444444444444444444411111111111111111111011111111100111111110011111111000111111100001111111111111111
1	2	2222222222222222222211111111111111111111011111111100111111110011111111000111111100001111111111111111
1	1	0000000000000000000000000000001111111111011111111100111111110011111111000111111100001111111111111111
2	3	4444444444444444444411111111111111111111011111111100111111110001111111000011111100001111111111111111
2	2	2222222222222222222211111111111111111111011111111100111111110001111111000011111100001111111111111111
2	1	0000000000000000000000000000001111111111011111111100111111110001111111000011111100001111111111111111
3	3	4444444444444444444411111111110111111110011111111100011111110000111111000001111100000111111111111111
3	2	2222222222222222222211111111110111111110011111111100011111110000111111000001111100000111111111111111
3	1	0000000000000000000000000000000111111110011111111100011111110000111111000001111100000111111111111111
4	3	4444444444444444444411111111111111111111011111111100111111110001111111000111111100001111111111111111
4	2	2222222222222222222211111111111111111111011111111100111111110001111111000111111100001111111111111111
4	1	0000000000000000000000000000001111111111011111111100111111110001111111000111111100001111111111111111
5	3	4444444444444444444411111111111111111111011111111100111111110001111111000011111100001111111111111111
5	2	2222222222222222222211111111111111111111011111111100111111110001111111000011111100001111111111111111
5	1	0000000000000000000000000000001111111111011111111100111111110001111111000011111100001111111111111111
6	3	4444444444444444444411111111110111111111011111111100111111110001111111000011111100000111111111111111
6	2	2222222222222222222211111111111111111111011111111100111111110001111111000011111100001111111111111111
6	1	0000000000000000000000000000001111111111011111111100111111110001111111000011111100001111111111111111

See Table 12 for explanation.

Table 15. Corn optimal decision for stages 7-35 with cost of storage = $.36/bu/yr.

Stage	Stock State	Optimal decisions for each price state combination
7	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
7	2	2222222222222222222211111111101111111110111111111 0011111111000111111100001111110000011111111111111
7	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000011111111111111
8	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
8	2	2222222222222222222211111111101111111110111111111 0011111111000111111100001111110000011111111111111
8	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000011111111111111
9	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
9	2	2222222222222222222211111111101111111110111111111 0011111111000111111100001111110000011111111111111
9	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000011111111111111
10	3	1111111111111111111111111111111111111110111111111 0011111111000111111100001111110000111111111111111
10	2	2222222222222222222211111111111111111110111111111 0011111111000111111100001111110000111111111111111
10	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000111111111111111
11	3	1111111111111111111111111111111111111110111111111 0011111111000111111100011111110000111111111111111
11	2	2222222222222222222211111111111111111110111111111 0011111111000111111100011111110000111111111111111
11	1	0000000000000000000000000000001111111110111111111 0011111111000111111100011111110000111111111111111
12	3	1111111111111111111111111111111111111110111111111 0011111111001111111100011111110000111111111111111
12	2	2222222222222222222211111111111111111110111111111 0011111111001111111100011111110000111111111111111
12	1	0000000000000000000000000000001111111110111111111 0011111111001111111100011111110000111111111111111
13	3	1111111111111111111111111111111111111110111111111 0011111111001111111100011111110000111111111111111
13	2	2222222222222222222222222222221111111110111111111 0011111111001111111100011111110000111111111111111
13	1	0000000000000000000000000000001111111110111111111 0011111111001111111100011111110000111111111111111
14	3	1111111111111111111111111111111111111110111111111 0011111111000111111100001111110000111111111111111
14	2	2222222222222222222222222222221111111110111111111 0011111111000111111100001111110000111111111111111
14	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000111111111111111
15	3	1111111111111111111111111111101111111100111111111 0001111111000011111100000111110000001111111111111
15	2	2222222222222222222222222222201111111100111111111 0001111111000011111100000111110000001111111111111
15	1	0000000000000000000000000000001111111100111111111 0001111111000011111100000111110000001111111111111
16	3	1111111111111111111111111111111111111110111111111 0011111111000111111100011111110000111111111111111
16	2	2222222222222222222222222222221111111110111111111 0011111111000111111100011111110000111111111111111
16	1	0000000000000000000000000000001111111110111111111 0011111111000111111100011111110000111111111111111
17	3	1111111111111111111111111111111111111110111111111 0011111111000111111100001111110000111111111111111
17	2	2222222222222222222222222222221111111110111111111 0011111111000111111100001111110000111111111111111
17	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000111111111111111
18	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
18	2	2222222222222222222222222222201111111110111111111 0011111111000111111100001111110000011111111111111
18	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000011111111111111
19	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
19	2	2222222222222222222222222222201111111110111111111 0011111111000111111100001111110000011111111111111
19	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000011111111111111
20	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
20	2	2222222222222222222222222222201111111110111111111 0011111111000111111100001111110000011111111111111
20	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000011111111111111
21	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
21	2	2222222222222222222222222222201111111110111111111 0011111111000111111100001111110000011111111111111
21	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000011111111111111
22	3	1111111111111111111111111111111111111110111111111 0011111111000111111100001111110000111111111111111
22	2	2222222222222222222222222222201111111110111111111 0011111111000111111100001111110000111111111111111
22	1	0000000000000000000000000000001111111110111111111 0011111111000111111100001111110000111111111111111
23	3	1111111111111111111111111111111111111110111111111 0011111111000111111100011111110000111111111111111
23	2	2222222222222222222222222222221111111110111111111 0011111111000111111100011111110000111111111111111
23	1	0000000000000000000000000000001111111110111111111 0011111111000111111100011111110000111111111111111
24	3	1111111111111111111111111111111111111110111111111 0011111111000111111100011111110000111111111111111
24	2	2222222222222222222222222222221111111110111111111 0011111111001111111100011111110000111111111111111
24	1	0000000000000000000000000000000000000000111111111 0011111111001111111100011111110000111111111111111
25	3	1111111111111111111111111111111111111110111111111 0011111111000111111100011111110000111111111111111
25	2	2222222222222222222222222222221111111110111111111 0011111111001111111100011111110000111111111111111
25	1	0000000000000000000000000000000000000000111111111 0011111111001111111100011111110000111111111111111
26	3	1111111111111111111111111111111111111110111111111 0011111111000111111100001111110000111111111111111
26	2	2222222222222222222222222222201111111110111111111 0011111111000111111100001111110000111111111111111
26	1	0000000000000000000000000000000000000000111111111 0011111111000111111100001111110000111111111111111
27	3	1111111111111111111111111111101111111100111111111 0001111111000011111100000111110000001111111111111
27	2	2222222222222222222222222222200000000000111111111 0001111111000011111100000111110000001111111111111
27	1	0000000000000000000000000000000000000000111111111 0001111111000011111100000111110000001111111111111
28	3	1111111111111111111111111111111111111110111111111 0011111111000111111100011111110000111111111111111
28	2	2222222222222222222222222222200000000000111111111 0011111111000111111100011111110000111111111111111
28	1	0000000000000000000000000000000000000000111111111 0011111111000111111100011111110000111111111111111
29	3	1111111111111111111111111111111111111110111111111 0011111111000111111100001111110000111111111111111
29	2	2222222222222222222222222222200000000000111111111 0011111111000111111100001111110000111111111111111
29	1	0000000000000000000000000000000000000000111111111 0011111111000111111100001111110000111111111111111
30	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
30	2	2222222222222222222222222222200000000000111111111 0011111111000111111100001111110000011111111111111
30	1	0000000000000000000000000000000000000000111111111 0011111111000111111100001111110000011111111111111
31	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
31	2	2222222222222222222222222222200000000000011111111 0011111111000111111100001111110000011111111111111
31	1	0000000000000000000000000000000000000000011111111 0011111111000111111100001111110000011111111111111
32	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
32	2	2222222222222222222222222222200000000000011111111 0011111111000111111100001111110000011111111111111
32	1	0000000000000000000000000000000000000000011111111 0011111111000111111100001111110000011111111111111
33	3	1111111111111111111111111111101111111110111111111 0011111111000111111100001111110000011111111111111
33	2	2222222222222222222222222222200000000000011111111 0011111111000111111100001111110000011111111111111
33	1	0000000000000000000000000000000000000000011111111 0011111111000111111100001111110000011111111111111
34	3	1111111111111111111111111111111111111110111111111 0011111111000111111100001111110000111111111111111
34	2	2222222222222222222222222222200000000000011111111 0011111111000111111100001111110000111111111111111
34	1	0000000000000000000000000000000000000000011111111 0011111111000111111100001111110000111111111111111
35	3	1111111111111111111111111111111111111110111111111 0011111111000111111100011111110000111111111111111
35	2	2222222222222222222222222222200000000000011111111 0011111111000111111100011111110000111111111111111
35	1	0000000000000000000000000000000000000000000000000 0011111111000111111100011111110000111111111111111

See Table 12 for explanation.

decision is to sell whenever current price is less than $3.44/bu, irrespective of the lagged price value.

The optimal decisions for months 1-35 under scenario two are given in Tables 14 and 15. For months 1-6 and stock states two and three a producer should enter into a FOR contract if current price is less than $2.81/bu and should sell if current price is between $2.81-$3.34/bu, irrespective of lagged price state value. Under scenario two as under scenario one for months 7-35 a producer should sell whenever current price is less than $3.44/bu and the stock state is 3, irrespective of the lagged price state value. The last generality is that for months 12-35 with the grain in stock state 2, a producer should enter the FOR program when current price is below the release price.

Probability of Being in a Given Stock State

The conditional and unconditional probabilities of being in each stock state while following the optimal policy presented in this study were calculated for winter wheat. The conditional probabilities are given price at harvest what is the probability of being in the various stock states as the procuder follows the optimal policy. The unconditional probabilities, which do not depend on price at harvest, are based on the long run probability of each price state range. These unconditional probabilities are the conditional probability matrix premultiplied by the matrix of long run probabilities of each price range. Tables 16, 17, and 18 present the conditional and unconditional probabilities for selected months since harvest.

Table 16. Conditional probability of being in each stock state for selected months since harvest when following the optimal policy for winter wheat.

Midpoint of price state at harvest	Months Since Harvest and Stock States: 2				6				21				35			
	FOR	CCC LOAN	STORE	SELL	FOR	CCC LOAN	STORE	SELL	FOR	CCC LOAN	STORE	SELL	FOR	CCC LOAN	STORE	SELL
2.625	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	.93	0.0	0.0	.07	.89	0.0	0.0	.11
2.875	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	.91	0.0	0.0	.09	.85	0.0	0.0	.15
3.125	1.0	0.0	0.0	0.0	.996	0.0	0.0	.004	.88	0.0	0.0	.12	.81	0.0	0.0	.19
3.375	1.0	0.0	0.0	0.0	.99	0.0	0.0	.01	.83	0.0	0.0	.17	.77	0.0	0.0	.23
3.625	1.0	0.0	0.0	0.0	.96	0.0	0.0	.04	.78	0.0	0.0	.22	.71	0.0	0.0	.29
3.875	1.0	0.0	0.0	0.0	.92	0.0	0.0	.08	.71	0.0	0.0	.29	.65	0.0	0.0	.35
4.125	1.0	0.0	0.0	0.0	.83	0.0	0.0	.17	.62	0.0	0.0	.38	.56	0.0	0.0	.44
4.375	.996	0.0	0.0	.004	.72	0.0	0.0	.28	.51	0.0	0.0	.49	.46	0.0	0.0	.54
4.625	.96	0.0	0.0	.04	.57	0.0	0.0	.43	.40	0.0	0.0	.60	.36	0.0	0.0	.64
4.875	.32	0.0	.54	.04	.37	0.0	0.0	.63	.25	0.0	0.0	.75	.23	0.0	0.0	.77
5.125	.11	0.0	.53	.36	.21	0.0	0.0	.79	.14	0.0	0.0	.75	.13	0.0	0.0	.87
5.375-7.375	0.0	0.0	0.0	1	0.0	0.0	0.0	1	0.0	0.0	0.0	1	0.0	0.0	0.0	1

[a]Cost of Storage = $0.00/bu/yr.

Table 17. Conditional probability of being in each stock stage for selected months since harvest when following the optimal policy for winter wheat.

Midpoint of price state at harvest	Months Since Harvest and Stock States															
	2				6				21				35			
	FOR	CCC LOAN	STORE	SELL	FOR	CCC LOAN	STORE	SELL	FOR	CCC LOAN	STORE	SELL	FOR	CCC LOAN	STORE	SELL
2.625	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	.82	0.0	0.0	.18	.70	0.0	0.0	.30
2.875	1.0	0.0	0.0	0.0	1.0	0.0	0.0	.01	.78	0.0	0.0	.22	.65	0.0	0.0	.35
3.125	1.0	0.0	0.0	0.0	.99	0.0	0.0	.01	.72	0.0	0.0	.28	.60	0.0	0.0	.40
3.375	1.0	0.0	0.0	0.0	.96	0.0	0.0	.04	.65	0.0	0.0	.35	.53	0.0	0.0	.47
3.625	1.0	0.0	0.0	0.0	.91	0.0	0.0	.09	.57	0.0	0.0	.43	.46	0.0	0.0	.54
3.875	.998	0.0	0.0	.002	.82	0.0	0.0	.18	.48	0.0	0.0	.52	.39	0.0	0.0	.61
4.125	.97	0.0	0.0	.03	.68	0.0	0.0	.32	.37	0.0	0.0	.63	.30	0.0	0.0	.70
4.375 - 7.375	0.0	0.0	0.0	1	0.0	0.0	0.0	1	0.0	0.0	0.0	1	0.0	0.0	0.0	1

[a] Cost of storage = $.36/bu/yr.

Probabilities of being in different stock states were not calculated for corn due to very high computational costs.[9] With the FOR loan price being above the market equilibrium price and the storage payments under the FOR being the same for corn and winter wheat, it was felt that the corn probabilities would not differ greatly from the general trend in the winter wheat probability matrices.

Conditional: An important implication of the conditional probabilities for policy makers is the probability of being in the FOR after three years (Tables 16 and 17). For low price state values at harvest the probability of remaining in the FOR for three years is very high with both scenarios. When the price state value of harvest is between the FOR loan price and the FOR release price, the probability of being in the FOR after three years is approximately 0.5 for scenario 1. The probability for scenario 2 is around 0.3 for those intermediate prices at harvest. This suggests that as the program continues over the years, a large amount of grain will be held in the FOR.

Another interesting aspect of these probabilities is that within five months from harvest the probability of being in the CCC loan program or in storage without a federal loan is essentially zero under either scenerio. Two reasons that can be given for the FOR being so attractive to a producer are 1) storage payments and 2) the loan price being above the market equilibrium price.

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[9] Calculation of the probabilities for corn requires multiplication of 30 matrices with dimension 400 by 400.

Unconditional: Even a better measure of the value of the various federal programs is the unconditional probabilities of being in the different stock states. Unconditional probabilities are given in Table 18. If the optimal policy is followed, the unconditional

Table 18. Unconditional probability of being in each stock state for selected months since harvest when following the optimal policy for winter heat.

Stock State	Months Since Harvest 2	6	21	35
	Cost of Storage = $0.00/bu/yr			
FOR	.88	.79	.64	.54
CCC loan	0.0	0.0	0.0	0.0
Store	.04	0.0	0.0	0.0
Sell	.08	.21	.36	.46
	Cost of Storage = $.36/bu/yr			
FOR	.69	.62	.41	.33
CCC loan	0.0	0.0	0.0	0.0
Store	0.0	0.0	0.0	0.0
Sell	.31	.38	.59	.67

probabilities suggest that over 50 percent of the U.S. winter wheat crop that is eligible for the FOR program under scenario 2 will remain in the FOR for the three year contract.

Both conditional and unconditional probabilities suggest that as the FOR program continues over the years, a large amount of grain will be held in the FOR. This amount of grain in the FOR will have two major effects. The first is that it will have a depressing effect on winter wheat prices in the long run. The second effect deals with the federal program. As the amount of grain held in the FOR increases, storage payments also increase. Due to the increase in storage payments, the Secretary of Agriculture may be politically forced to put a ceiling on the amount of grain that can be held in the FOR or be forced to revamp the provisions of the FOR.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

This study presents a rigorous optimization routine that shows federal programs can increase the value of a bushel of grain to an expected profit maximizing producer. The federal program that increases the value of a bushel of grain the most is the FOR with its storage payments.

A risk neutral producer's optimal decision does not include going into the regular CCC loan program. For both corn and winter wheat under the two scenarios, taking out a regular CCC loan program was never the optimal decision. The regular CCC loan program eliminates downside risk while at the same time not sacrificing upside potential except for interest payments. The FOR also eliminates downside risk but some upside potential is lost, between the loan price and the release price. This loss in upside potential is made up by the storage payments and the premium loan under the FOR program.

The results of the DP model can be used to determine if a producer should reduce his acreage to qualify for the federal programs. The producer must determine if his expected profit under the federal program is greater than his expected profit outside of the federal program (acreage not reduced). Presented in this section is a method of how the results from the DP model can be used to determine the highest expected profit.

Data needed for the calculation includes total acres to be planted (A_{NR}), acres planted under federal program guidelines (A_R), expected yield per acre (Y), and cost of production per acre (C) along with the results from the DP program. Also needed would be the probability of each price state value at harvest. Given price at planting time, the probability of each price state value at harvest can be calculated by the transsition probability matrix generated by the price forecasting equation. The probability of each price state value is used to calculate expected returns.

The expected profit to a producer who sells at harvest and plants his total acreage can be calculated by the following equation:

$$E(\Pi) = E(P) \cdot Y \cdot A_{NR} - A_{NR}C$$

where

E(P) is expected price and

$E(\Pi)_{TA}$ is expected profit from planting total acreage.

By comparing expected profit from planting his total acreage to his expected profit from reduced acreage to comply with the federal regulations, a producer could decide if he is better off reducing his acreage or planting his total acreage. Expected profit from complying with federal regulation is calcuation by the following equation:

$$E(\Pi)_{RA} = E(FOPT) \cdot A_R \cdot Y - A_R \cdot C + E \text{ (other payments)}$$

where $E(\Pi)_{RA}$ is expected profit from reduced acreage;

E(FOPT) is the expected return of one bushel of grain from following an optimal policy, obtained from the DP results and the probability of each price state value at harvest; and

E(other payments) - expected other payments of the federal programs such as deficiency payments.

Another calculation is needed if the producer has the option of storing his grain instead of having to sell at harvest.

$$E(\Pi)_{TA} = E(SOPT)A_{NP} \cdot Y - A_{NP} \cdot C$$

where

E(SOPT) is expected returns for one bushel of grain from storing the grain so it can be sold at a later date or sell at harvest for each price state value.

SOPT would be obtained by finding the optimal returns for each price state value, by considering only two decision alternatives, sell or store.

For a producer who wants to maximize expected profit he would comply with the federal regulations if $E(\Pi)_{RA}$ was greater than $E(\Pi)_{TA}$. If $E(\Pi)_{TA}$ was greater than $E(\Pi)_{RA}$, the producer would plant his total acreage and not participate in the federal program.

Limitations of the Model

The major potential limitation of this study is that the decision rules are valid only to the extent that the transition probabilities are valid. The price forecasting equations that were estimated used past values to predict future cash market prices. The critical issue is if these equations are applicable to probablilistically predicting future cash market prices. These equations were based on ten years of data, but the FOR program was in effect for only the last four years. The first FOR loans are now just becoming due and the time series equations have no basis to handle the effects on price of this added grain on the market or in the hands of the CCC. This effect, if any, on price can be measured only with more years of data on market price with the FOR in place.

Another problem is related to how well producers expectation of prices correspond to the expectation of prices given by the time series equations. If they do not correspond, the time-series models are not an appropriate foundation for computing subjective expected profits to a producer; thus the decision rules presented in this study would not be satisfactory in this sense.

A third problem associated with the price equations deals with the truncation of prices at the release level. The longer the FOR is in effect the greater its affect on price. As the amount of grain stored under the FOR increases, market price will be depressed in the long run. The decrease in price will increase the probability of being in the FOR for the length of a contract. The above effect on supply, and thus prices, will cause the truncation of market prices at the release price. Grain will only be on the market when market price is above the release price. If this truncation occurs it will cause the transition probabilities generated in the DP model to be invalid, thus invalidating the decision rules presented in this study.

Hedging was not considered in this study, in part because not many producers hedge, but more importantly because hedging is a risk management tool and not an expected profit maximizing strategy. Thus, since this study assumed risk neutrality, hedging was dominated by other strategies.

A third limitation of the study is that risk aversion was not considered. Risk aversion may imply that a producer should follow some type of split strategy, such as selling some of the crop at harvest, putting part in the FOR and putting some of the crop in the regular CCC loan program.

Recommendations for Further Study

This study shows that federal programs can increase the expected value of a bushel of grain when market prices are low. This increase in value suggests that producers should store their grain when prices are low rather than selling grain during the year following harvest. Further studies should focus on the impact that these federal programs will have on market price when the federal contracts become due. Another aspect of the federal programs that should be examined is the effect the regulatations required to participate in the program have on a producer. Reduced acreage is required to be eligible for the FOR and regular CCC loan programs. A question that needs to be answered in a rigorous optimization routine is, is a producer better off to reduce his acreage and enter the federal programs or is a producer better off to plant all of his acreage and not participate in the federal programs? A third question that needs to be looked at is what happens to a producer who reduces his acreage to comply with the federal program regulations, after which the Secretary of Agriculture imposes a ceiling on the amount of grain that can be put into the reserve. This producer does not get the benefits of the FOR program but he has reduced his crop acreage so his profit will be reduced.

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APPENDIX

APPENDIX

A mathematical treatment of how the Markovian transition probabilities were calculated is presented in this appendix. The transition probabilities, which are vital to the decision rule, give the probability of price at time t + 1 given the price information vector PI_t at time t. For winter wheat this price information vector contained only current price, giving first order Markovian transition probabilities. The corn price information vector contained two values, current price and price lagged once, which gives second order Markovian transition probabilities.

Notation used in this appendix is: MP is the state index for time t-1; IP is the state index at time t; and JP is the state index at time t + 1. States indices MP and IP make up the price information vector. Each price state (MP, IP, JP) is a range of prices. The transition probabilities for both wheat and corn were calculated in the same general way. The only difference being the state MP for corn.

A value for the midpoints of states MP and IP were obtained. These values were used in the price forecasting equations, developed in Chapter 3 to obtain the market price at the next state,

$$\log P_{t+1} = \varepsilon - \log f(\mathrm{MP}, \mathrm{IP}, \text{monthly variation})$$

where ε is the multiplicative error term for the regression equation $f(\cdot)$.

Since the price states are a range of values, an upper (PU) and a lower (PL) limit for state JP at time t + 1 can be calculated. These limits, upper and lower, imply that an upper and lower error term can be associated with each state JP. To standardize these error terms, they were divided by the standard deviation (SD) of the price forecasting equation.

$$ZU = \frac{\log [PU] - \varepsilon}{SD}$$

$$ZL = \frac{\log [PL] - \varepsilon}{SD}$$

ZU and ZL are the standard normal upper and lower limits for the error term.

An hypobolic tangent equation, which approximates a normal cumulative probability distribution (CDF), developed by Taylor (1981) was used to generate the transition probabilities.

$$FU = .5 + .5 \tanh (.7971 \times ZU + .03731 \times ZU^3 + .003923 \times ZU^5)$$

$$FL = .5 + .5 \tanh (.7971 \times ZL + .03731 \times ZL^3 + .0003923 \times ZL^5)$$

These two equations given an upper and lower value of the approximated CDF, substracting the two values given the probability of going to state JP_{t+1} given states IP_t and MP_{t-1} (see Figure 3).

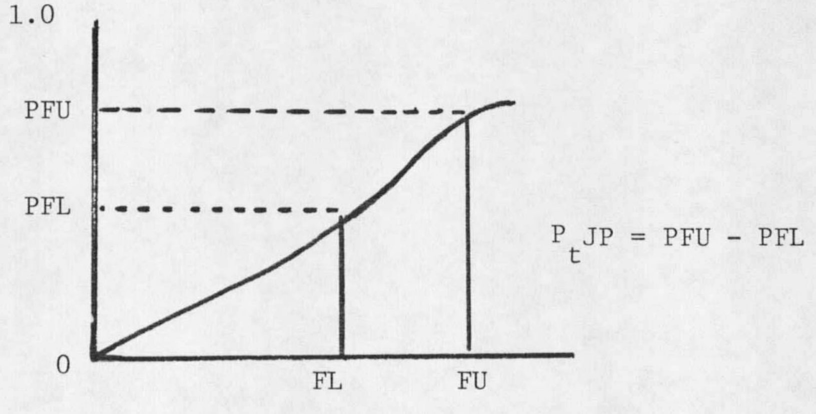

Figure 3. An illustration of calculation of transition probabilities.