An Economic Analysis of Carryover Policies for The United States Wheat Industry

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INTRODUCTION

Stabilization of farm prices and incomes has been a major objective of commodity programs for four decades. To achieve this objective, the government has used means including direct payments, production controls, subsidized exports, and, to a lesser extent, commodity storage. The "stabilization" function has had at least two dimensions for farm prices and incomes: raising their level and reducing their variability.

With growing demands for public funds for other national problems and realization that benefits of higher levels of farm prices and incomes are lost through capitalization of benefits into farmland, increasing attention is focusing on the second dimension of commodity programs: reducing the variability in farm prices and incomes. An important issue is whether carefully formulated commodity storage policies, either alone or in combination with other measures such as production control, can reduce the variability of farm prices and incomes to reasonable levels at low Treasury cost.

The Reserve Management Problem

Uncertainties in wheat prices and receipts stem from variation in supply and demand. On the demand side, the major source of variation is in the demand for export: domestic demands change very little from year-to-year, but export demand varies widely as foreign production fluctuates and as economic assistance programs change.

On the supply side, variation arises from two sources: yield per acre and acreage planted. Government farm programs of recent years have demonstrated their ability to influence acreage planted to the extent that this can be considered a policy variable and not a random

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variable. Yield per acre is subject to considerable random variation, mainly due to effects of uncertain weather conditions.

If quantities are not sometimes stored from one year to the next, the interaction of variations in exports on the demand side and in yields on the supply side have potentially undesirable effects. Supplies that are very small relative to demands result in high prices and/or short supplies—a situation undesirable to consumers, domestic and foreign. Instabilities caused by wide fluctuations in prices and incomes that unchecked supply and demand can bring are undesirable to farmers, many of whom must meet annual cash obligations on mortgages, family living and other items.

Producers like to see prices raised by taking commodities off the market for storage, but do not like to see stocks released. If reserve management rules could be soundly developed and well established with preset guidelines so that farmers always know what the rules are, there might be less distrust among farmers toward inventories being held by government and less chance that a program would be subject to changes made for political advantage.

Objectives

The objectives of this study are to:

1. Develop an aggregate model of the United States wheat economy suitable for use as a vehicle to examine the efficiency and effectiveness of rule-of-thumb and other wheat reserve management policies; and

2. Estimate and evaluate the results from implementing management policies in (1). Evaluation will focus on the level and variability of economic variables such as wheat price, farm income, and social benefits.

Procedure

A stochastic computer simulation model is developed to evaluate the effectiveness of various inventory policies. The simulation model developed for this project is of the Monte Carlo type and contains built-in stochastic processes to approximate uncertain yield and export demand. Various runs of the model generate data used to compare different inventory policies and market characteristics. The model developed here and the empirical analyses apply directly only to wheat, but could be extended, with some modifications, to other storable agricultural commodities.

Review of Literature

Attention has been directed toward the grain inventory management problem — or at least toward determining satisfactory reserve levels — in relatively few economic analyses. In a 1952 study [3] for the Senate Agricultural and Forestry Subcommittee, Karl Fox and O. V. Wells analyzed historical yield and consumption variations to determine probabilities associated with various production deficits over a two-year period. It was determined that a reasonable storage objective would be to stock sufficient quantities to offset one year of very low yield (an adjusted average of the five lowest yields) followed by one year with a moderately low yield (average of the next 20 lowest yields). They then concluded that reserves of 500 million bushels of wheat, 1 billion bushels of corn and 5 million bales of cotton would provide reasonably good protection.

Robert L. Gustafson [4] in 1958 used a procedure which maximized over time a measure of public benefits measured by the area (dollar value) under any given grain demand curve. Gustafson developed an optimal set of storage rules which tell, for each possible supply and for several different market conditions and storage costs, the quantity of grain to place into storage to maximize the expected public benefits. Explicit account is taken of the stochastic nature of output and of the intertemporal dependence of supplies and decisions. Application of the technique to feed grains was accomplished by approximate numerical and graphical methods.

Frederick V. Waugh [11] in a study conducted by the National Food and Fiber Commission in 1967 concluded that satisfactory goals for storable farm products are as follows: wheat, 550-650 million bushels; corn, .8-1.0 billion bushels; four feed grains, 35-40 million tons; rice, 10-12 million hundredweight; and cotton, 5-6 million bales. Waugh's study extended the analysis of Fox and Wells by considering probable future variations in demand and substitution possibilities more explicitly. The quantitative analysis culminated in graphical relationships between percentages of years for which production had been less than a certain percentage of the trend. It was considered desirable to be protected by reserves against below-trend production.

Vernon R. McMinimy and Francis A. Kutish [6] also discuss a reserve program for wheat and feed grains, pointing out possible objectives of such a program and the factors which should be considered in any model which attempts to determine United States reserve levels.

A SIMULATION MODEL TO STUDY RESERVE MANAGEMENT POLICIES

Simulation as used in economic research entails construction of an economic model which incorporates as many variables and relationships as is necessary to approximately characterize the conditions of a real economic system. A single run of the simulation model iteratively generates a stream of behavior for endogenous variables that would be expected in the real world under similar conditions. Some of the variables considered important include social cost, storage cost, farm income, commodity price and utilization, and inventory levels. Depending on the construction of the model, interest may center on the magnitude, stability, or on the adjustment patterns of these variables. Results of a particular iteration are specific to structural conditions and chance elements in that iteration, but repeated iterations average out chance elements and allow the system to be audited in a general manner. Each run of many iterations may be thought of as an experiment, allowing investigations of hypotheses and outcomes of various alternative courses of action without being forced to try costly alternative policies in the real system.

Monte Carlo and simulation techniques are combined to make the model stochastic. If some variables or relationships must be characterized as random, stochastically following some theoretical or empirical distribution of probability, then a value of each stochastic variable is randomly selected from an apropriate probability distribution during each iteration. Data generated by the model usually consist of a great number of iterations—the output or ending state of the system being used as the input or beginning state for the succeeding iteration. The behavior stream in this case is stochastic: the behavior of relevant variables may be analyzed in terms of ordinary statistics such as means, measures of variation, or in terms of frequency counts or histograms to indicate the likelihood of certain stochastic outcomes.

Characteristics of the Wheat Reserve Management Simulation Model

General characteristics of a simulation model developed to investigate wheat carryover problems are presented below. Because this model varies somewhat for each type of carryover policy under consideration, the exact specification of the variables and parameters will be discussed later as the results are presented. The framework of the model and the numerical values of various parameters were established after due consideration to several factors including workability, *a priori* and statistical information after consultation with persons in the grain trade, some of whom were knowledgeable in the use of econometric techniques as well as in the characteristics of the grain trade.

Several terms may be used to describe the model. For example, it may be appropriately described as an equilibrium model: price and utilization are determined by the economic requirement that the supply quantity and demand quantity must be equal for each period. The model is also aggregative: total demand at each price is the horizontal summation of sector demands. Demand components considered include: (1) domestic food, seed and industry, (2) feed, (3) export, and (4) stocks or carryover. Demand for stocks takes several forms throughout the analysis depending on the particular carryover policy being studied while the remaining demand elements are, for the most part, kept in the same form.

The model is also stochastic. Short-run (one-period) supply is the sum of carryover from last period and the current production, which is, in turn, the product of acreage and yield. Yield is a random variable, assumed to follow a discrete empirical distribution shown later.

Export demand is also assumed to be influenced by random processes, since deterministic mathematical relationships developed from time series data do not predict annual exports with much reliability.

The actual simulation is accomplished by first formulating the model into a mathematical framework, then transforming these relationships into Fortran IV language to execute the computer simulation. Figure 1 is a simplified flow diagram of the model. The portion labeled A is executed each period (one marketing year), generating simulated time series for each variable. After simulating many years, summary statistics are computed for each key economic variable.

Enough years are simulated so that the series of key variables reflect a stable situation. There is no purely objective way to arrive at an optimal number of iterations (years). To get some idea of the number of iterations required, several experiments were performed on the model, keeping cumulative means of several variables and plotting these against the number of iterations. The percentage improvement in stability of cumulative means became small after about 4000 iterations. Most actual runs used 4000 iterations except those for which the policies under consideration caused disequilibrium conditions and resulted in excesses such as unacceptably large buildup of stocks.

The starting point for the simulation analysis was the equilibrium supply-demand quantity of 1,550 million bushels associated with a normal acreage of 62 million and a normal yield of 25 bushels per acre. These values represent hypothetical "normal" values that would be expected to result under conditions of complete certainty and rational

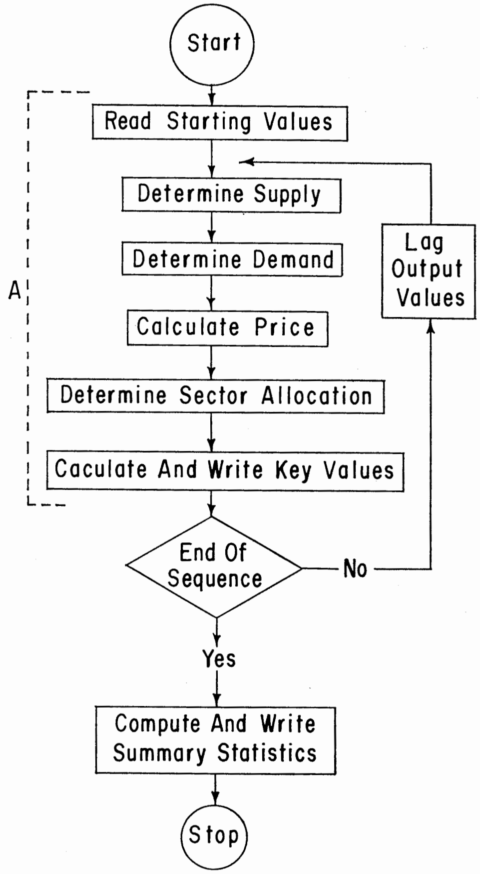

Figure 1. Continuous Representation of the Discrete Dynamic Simulation Results Relating Optimal Carryover to Total Supply

decisions as well as expected values (in the statistical sense) of the stochastic variables in the dynamic model. The entire model was designed to apply to the 1970 structure of the wheat industry.

To avoid repeatedly stating the units in which variables are expressed, variables will be expressed in the units shown in Table 1 throughout the remainder of this report—in the text discussion and equations, and in tables and figures—unless clearly noted otherwise.

Table 1. Notation and Units for Variables Used in Study.

Variable	Notation	Units
Quantity	Q	Million bushels
Yield	Y	Bushels per acre
Price	P	Cents per bushel
Acreage	A	Million acres
Income	--	Million dollars
Costs	--	Million dollars

Wheat Demand Relationships

The assumed demand relationships are given below:

$$QH_t = 595. - .25P_t \qquad \text{all } P \tag{1}$$

$$QF_t = \begin{cases} 100.00 & P > 130 \\ 1270. - 9.0P_t & P \leq 130 \end{cases} \tag{2}$$

$$QE_t = 596.25 - 3.3125P_t + .75QE_{t-1} + \varepsilon \tag{3}$$

P is wheat price,

QH is quantity consumed by the domestic food, seed, and industry sector,

QF is the quantity consumed by the domestic feed sector, and

QE is the quantity exported.

The food and feed schedules, QH_t and QF_t, were adapted from those developed by Tweeten [9, pp. 8-15] in 1965, adjusted to reflect subquent developments in usage patterns. ε in (3) is the stochastic element of the export demand equation randomly chosen from the allowable set of numbers for each iteration. The effect of ε is to randomly shift the entire demand function horizontally right or left by an amount less than or equal to 200. Under equilibrium conditions ($P = 120$, $QE_t = QE_{t-1} = QE_{t-2} = \ldots$), $QE_t = 795$ and the effect of ε is to allow the quantity intercept to fall uniformly between 992.5 and 1392.5. ε was chosen to have a uniform distribution:

$$f(\varepsilon) = 1/400; \ \varepsilon = -200, -199 \ldots, -1, 0, 1, \ldots, 198, 199.$$

Past data gave no evidence to reject the hypothesis that the non-systematic portion of exports follows a rectangular pattern.

The distributed lag formulation is of the Koych-Nerlove type, and is expressed by the linear equation:

$$Q_t = a + b_1P_t + b_2Q_{t-1},$$

where the short-run price elasticity is given by $b_1 \left(\frac{P}{Q}\right)$ and the long run elasticity by $\frac{b_1}{1-b_2} \left(\frac{P}{Q}\right)$. P and Q are points on the function where the elasticities are to be measured. Equation (3) is of this form and has short-run elasticity of —.5 and long-run elasticity of —2.0 at the equilibrium price of 120 and an assumed export equilibrium of 795 million bushels (when $\varepsilon = 0$, its expected value).

Table 2 gives more detail on characteristics of the export demand function. The table shows the effects on the quantity taken and on the demand elasticity of certain values for the random number ε and for QE_{t-1}, exports in the preceding period. As ε and QE_{t-1} increase, resulting in a rightward shift of the linear demand function, exports become less elastic at each price.

Sector demand equations (1), (2) and (3) give rise to the following aggregate demand $Q_t = QH_t + QF_t + QE_t$:

$$Q_t = \begin{cases} 1291.25 - 3.5625P_t + .75QE_{t-1} + \varepsilon & P > 130 \\ 2461.25 - 12.5625P_t + .75QE_{t-1} + \varepsilon & P \leqslant 130 \end{cases} \qquad (6)$$

Figure 2 shows the sector and aggregate demand functions assuming $\varepsilon = 0$ and an equilibrium value of 795 for QE_{t-1}. Table 3 gives additional information about the characteristics of the demand schedules. This table shows, for three selected prices, the quantities that would be taken and the short-run price elasticities at each point for individual and aggregate demand functions.

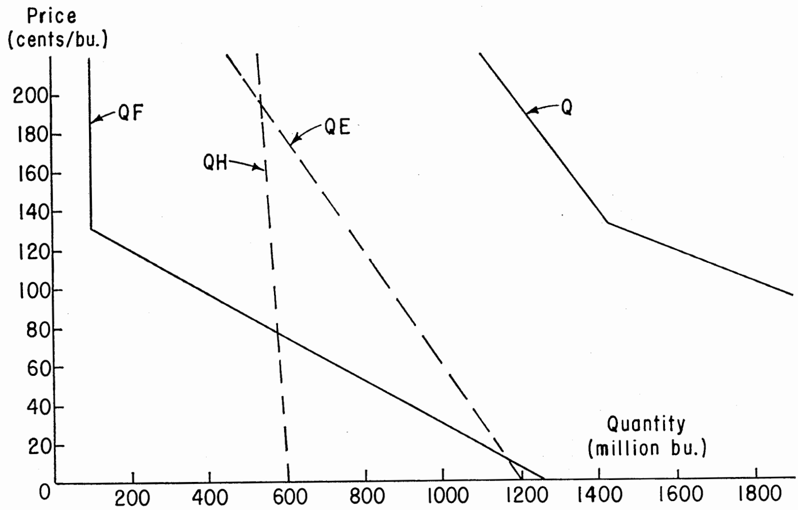

Figure 2. Food, Feed, Export and Aggregate Demands

Table 2. Export Demand Function Characteristics.

Price	ε	QE_{t-1}[1]	QE_t[1]	Short-Run Elasticity	Long-Run Elasticity
100	—100	700	690	—.48	—1.92
		795	761	—.44	—1.74
		900	840	—.39	—1.58
	0	700	790	—.42	—1.68
		795	861	—.38	—1.54
		900	940	—.35	—1.41
	100	700	890	—.37	—1.49
		795	961	—.34	—1.38
		900	1040	—.32	—1.27
120	—100	700	624	—.64	—2.55
		795	695	—.57	—2.29
		900	774	—.51	—2.05
	0	700	724	—.55	—2.20
		795	795	—.44	—2.00
		900	974	—.45	—1.82
	100	700	824	—.48	—1.93
		795	895	—.44	—1.78
		900	974	—.41	—1.63
140	—100	700	558	—.83	—3.32
		795	629	—.74	—2.95
		900	708	—.66	—2.62
	0	700	658	—.70	—2.82
		795	729	—.64	—2.54
		900	808	—.57	—2.30
	100	700	758	—.61	—2.45
		795	828	—.56	—2.24
		900	908	—.51	—2.04

[1] Units correspond to those given in Table 1.

Table 3. Demand Function Characteristics: Quantity Demanded and Short-Run Elasticity at Three Prices

	Price	Food	Feed	Export	Total
Quantity[1]	100	570.0	370.0	861.3	1801.3
	120	565.0	190.0	795.0	1550.0
	140	560.0	100.0	728.8	1388.8
Elasticity	100	—.044	—2.432	—.385	—.697
	120	—.053	—.5684	—.500	—.972
	140	—.063	0.0	—.636	—.359

[1] Units correspond to those given in Table 1.

Wheat Supply Relationships

In the simulated system, the quantity of wheat available each period for all purposes, including demand by the three consuming sectors and for stock or carryover, is the sum of production in the current period and carryover from the previous period. Since current production is the product of yield and acreage, both supply and production are fixed amounts for the period: short-run supply is functionally represented as $X_t = a$, a vertical line independent of price for this period.

Yield is a random variable having a mean of 25 bushels per acre and the empirical density function given in Table 4. This distribution was developed by grouping the deviations about a linear trend into one-bushel-increment classes added to an assumed "normal" 1970 yield of 25 bushels per acre. For a particular period in the simulation analysis, yield is selected by means of a random number generator which randomly assigns a value of Y according to the distribution of probability, g (Y).

Two different decision processes were used to determine acreage. One considered acreage to be determined by the market. This corresponds to a free-market (on the supply side) situation, without government intervention. The other assumes the acreage decision to be an autonomous policy decision, imposed on the producer by the government or a producer organization, but not necessarily independent of market conditions. This corresponds to a situation in which acreage quotas are set by policy makers based on inventory, anticipated needs, yields, and/or other policy considerations. For purposes of comparison, a particular carryover policy was simulated using each of the acreage decision processes.

The acreage function is a linear, cobweb-type distributed lag equation which gives a short-run elasticity of .3 and a long-run elasticity of

Table 4. Emperical Probability Distribution of Yield.

Yield Y	Probability g(Y)	Cumulative Probability G(Y)
—bushels per acre—		
21	.0625	.0625
22	.0208	.0833
23	.1250	.2083
24	.2083	.4167
25	.2292	.6458
26	.1250	.7708
27	.1042	.8750
28	.0833	.9583
29	.0208	.9791
30	.0209	1.0000

1.0 at the equilibrium values of 62 million for acreage and 120 for price (equation 7).

$$A_t = .155P_{t-1} + .70A_{t-1}. \qquad (7)$$

To represent the decision process when acreage is set in accordance with predetermined policy goals requires knowing what these goals are. For purposes of this analysis, it is assumed that the proper goal is to set acreage at a level which is most likely to meet expected needs plus or minus an amount necessary to adjust stocks to a "desired" level. Three levels of carryover — 200, 400, and 600 million bushels — were arbitrarily selected to represent this "desired" carryover, and each reserve management policy is examined with acreages set to satisfy each desired carryover level.

Notationally,

$$A_t = \frac{QP}{YP} + \frac{C^* - C_{t-1}}{YP}, \qquad (8)$$

where

C^* is desired or target carryover,

QP is the predicted or expected demand quantity, and

YP is the predicted or expected yield.

The first term gives the acreage necessary to meet expected needs, the second is the adjustment in acreage required to achieve the desired stock adjustment. For purposes of simplicity, QP is the aggregate demand quantity at equilibrium conditions ($QP = 1550$), and YP is set at the expected value of Y, 25 bushels per acre.

More complicated decision rules could be devised to account for various exigencies in expected demand (as a critical world food situation, for example), or to incorporate more variables into the process.

Miscellaneous Calculations

In addition to price and quantity, the values of several other variables were calculated each period to compare more completely the various reserve stock management policies. The most important of these are social cost or loss, income derived from wheat production, and costs of storage.

The model requires that a value to society be placed on quantities stored. Only in this way can storage alternatives be chosen to maximize that value. Tweeten and Tyner [10] proffer a utility concept of net social cost which will be used as one policy criterion for this study. This concept states that the net social cost from failure to utilize those quantities which exactly correspond to the economic equilibriums is given by the area bounded by the demand and supply curves and by the deviation of quantities actually utilized from the equilibrium quantity. This cost (or benefit foregone) is the difference between utility gained (or total social benefit) as measured by the area under the market demand curve and total utility foregone as measured by the area under the market supply curve.

If the total supply available (this year's production plus carryover from last year) is less than or equal to an assumed equilibrium quantity, carryover is considered to be zero. In this case the area between the demand and supply curves and bounded on the left by the quantity actually supplied and on the right by the equilibrium quantity is a measure of net social benefits foregone. This is shown for one period as the shaded area ABG in Figure 3 where Q* is equilibrium quantity and S′ is total available supply and also quantity actually utilized.

If the supply available is greater than the equilibrium quantity, it is assumed that carryover will be positive. A measure of social cost is then given by the area between the supply and demand curves bounded on the right by the quantity actually utilized — supply less carryover. In Figure 3, S is the total available supply, C is the carryover into the next period and Q is the quantity actually utilized so that net social cost is given by the shaded area CDG and is a decreasing function of the level of carryover Also in this case, an additional cost is incurred in the form of storage cost which is an increasing function of the level of carryover.

If carryover costs were zero, social cost minimization would simply require that carryover be sufficient to cause Q* to be used each period, or if supply were not random, there would be no need for carryover (as-

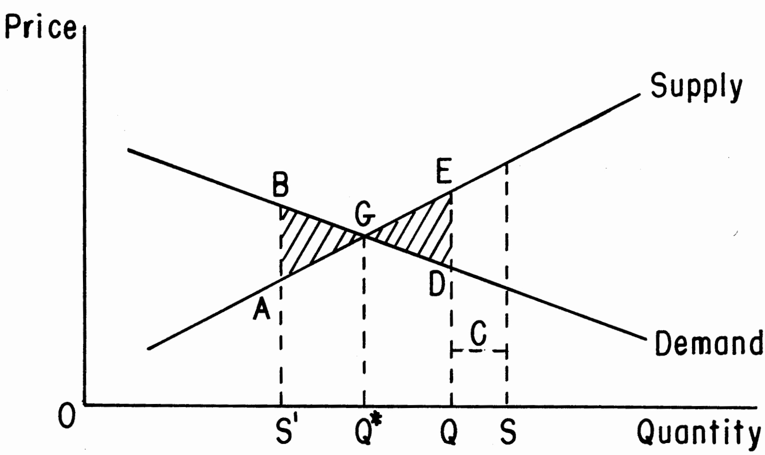

Figure 3. Illustration of Net Social Cost and Net Social Benefit Foregone

suming the demand and supply schedules were known with certainty). But with positive carryover costs and random yields, the minimum total social loss occurs when carryover makes possible a quantity actually utilized that is greater than Q* and less than S. For any one period, then, the total loss is either the net social benefit foregone or the net social cost plus the storage cost. The total loss for the planning period is the sum of the losses for each year in the planning period.

The supply function used to calculate social cost in the simulation process is equation (9). This function has a constant elasticity of .3

$$P_{S_t} = \begin{cases} \left(\dfrac{Q_t}{358.521}\right)^{10/3} & Q_t > 1550 \\ -280 + .2581\ Q_t & Q_t \leqslant 1550 \end{cases} \tag{9}$$

through the point of normal equilibrium, and is linear for quantities and prices greater than equilibrium. This market equation is the planning supply function and is assumed to remain constant for all periods.

The demand function used in the social cost calculation is an aggregate, for that period, of schedules of each consuming sector. Because of the dynamic and stochastic nature of the export demand equation, this aggregate function is different for each period and does not necessarily pass through the assumed equilibrium point. This formulation is necessary because the "normal" equilibrium (price = 120, quantity = 1550) would result only if there were no uncertainties or dynamic elements. Stochastic and dynamic elements of the export equation shift demand and cause the equilibrium to vary from period to period.

When wheat is stored from one period to the next, it is assumed that the marginal and average cost of this storage is 15 cents per bushel. The sum of the social cost and the carryover cost is the total social loss incurred for the period. This loss function is equation (10), where P_{Dt} is the

$$L(S,C) = \begin{cases} \displaystyle\int_{S_t}^{Q^*} (P_{D_t} - P_{S_t})\,dq & S_t \leq Q^* \\ R(C_t) + \displaystyle\int_{Q^*}^{S_t - C_t} (P_{S_t} - P_{D_t})\,dq & S_t > Q^* \end{cases} \tag{10}$$

inverse function of Q_t, given as equation (6) earlier, P_{S_t} is from equation (9), and

$$R(C_t) = .15\ C_t. \tag{11}$$

No provision is made within the model to distinguish between the portions of storage costs borne by government agencies and by private concerns.

The income items recorded in the simulation analysis are total gross and net incomes from wheat production. Gross income is calculated as the product of price and quantity marketed each period, while net income includes a fixed per acre charge for cost of production. This charge represents all variable costs of production and is assumed to be a constant $20 per acre for all levels of yield and acreage. Notationally,

$$GI_t = P_t \cdot Q_t, \tag{12}$$

$$NI_t = GI_t - 20\ A_t. \tag{13}$$

The Three Basic Reserve Management Models

Model I

The first inventory model (Model I) approximates a free market situation in which the stocking function is performed by the private sector according to supply-demand conditions within the industry. The quantity stored each period is determined by a functional relationship representing demand for stocks as an element of total demand. In terms of a reserve management policy, the operation of the model represents a "hands-off" policy. The proper policy with respect to reserves is to assume that private dealers and speculators will keep adequate reserves to meet emergency needs as they pursue normal profit-taking operations.

Based on the stocks demand equation, the equilibrium carryover is 400 million bushels. The price elasticity of demand for stocks is —1.2375 at a price of 120 and is zero for prices above 200 [cf. 9, p. 11]. This makes a quantity of 70 million bushels a lower limit for carryover from one period to the next. The explicit forms of the demand-for-stocks function and the new aggregate demand which results from this formulation are given as QS_t and Q'_t in equations (14) and (15).

$$QS_t = \begin{cases} 70 & P > 200 \\ 895. - 4.125\ P_t & P \leqslant 200 \end{cases} \tag{14}$$

$$Q'_t = \begin{cases} 1361.25 - 3.5625\ P_t + .75\ QE_{t-1} + \epsilon & P > 200 \\ 2186.25 - 7.7875\ P_t + .75\ QE_{t-1} + \epsilon & 130 \leqslant P \leqslant 200 \\ 3356.25 - 16.6875\ P_t + .75\ QE_{t-1} + \epsilon & P \leqslant 130 \end{cases} \tag{15}$$

Figure 4 is a static, one-period example of the operation of Model I. QS is the inventory demand function, Q the aggregate demand not including QS, and Q′ the sum of Q and QS. The aggregate demand functions are drawn assuming $\varepsilon = 0$ and $QE_{t-1} = 795$, their expected or

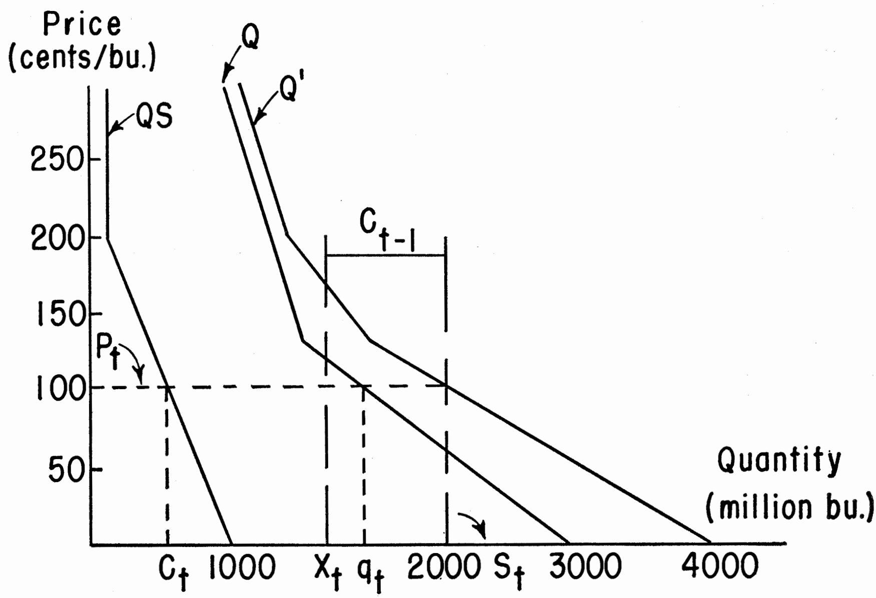

Figure 4. Static Example of the Operation of Model I

normal values. If production in the current period (X_t) is 1475 and carryover from last period (C_{t-1}) is 775, then the total supply (S_t) available for all uses, including stocks, is 2250. The price is 103. Of the total supply of 2250, 470 (C_t) will be carried over into the next period and 1780 (q_t) allocated to the three consuming sectors.

Model II

The second inventory model uses stocks as an instrument for achieving interrelated goals of domestic market stability and reserves to meet emergency needs, both foreign and domestic. The operation of this model approaches that sought by the ever-normal granary idea of the 1930's as well as more current ideas as suggested by Senate and House of Representative bills S.2617, S.2743, S.2233 and H.R.14329 introduced during the First Session of the 90th Congress, but not enacted into law.

Each of these bills provides for adding to current stocks if reserves fall below an established safety level (about 20 percent of estimated export and domestic needs) provided the purchases can be made at or below a certain price (typically, 115 percent of the price support loan rate). Provisions are made to dispose of the stocks if the market price reaches a certain upper level (say 145 percent of the loan rate, or 100 percent of parity) even if carryover is expected to be below the established safety level. These provisions are designed to insulate stock adjustments from ordinary market operations during periods of reasonably normal demand and supply conditions. The adjustments in stocks would be made only during years in which a shortage or surplus would otherwise result.

Model II provides for an adjustment to be made in inventory only if price reaches certain prescribed levels. Stocks will be decreased (and quantity marketed increased) when the price reaches P^U, a pre-determined distance above the equilibrium price, and will be increased (decreasing the quantity placed on the market) when price falls to P^L, a predetermined distance below the equilibrium price. Otherwise, the quantity marketed, Q, will be the amount produced, X_t.

With reference to Figure 5, if total supply X_t is greater than Q_t^U, inventories will be adjusted to bolster price up to the lower limit P^L. For example, assume X_t is x_4. Then $x_4—Q_t^U$ will be added to stocks (and subtracted from X_t) so that Q_t will be placed on the market at a price of P^L. Total carryover into the next period is $C_t = C_{t-1} + (X_t — Q_t^U)$. This operation is restricted by the assumption that institutional factors will limit U. S. wheat inventory to no more than 1 billion bushels. If the adjustment in stock necessary to increase price to P^L is enough to cause carryover to be above 1 billion bushels, the excess will be marketed, causing the market price to be below P^L.

When production is less than Q_t^L, the opposite adjustment takes place. If X_t is x_1, $(Q_t^L - x_1)$ will be taken from reserves and placed on the market along with S_t so that Q_t^L will be sold at a price of P^U. Carryover into the next period will be $C_t = C_{t-1} - (Q_t^L - X_t)$ or $C_t = C_{t-1} + (X_t - Q^L)$. This operation is subject to the obvious restriction that stocks cannot be reduced below zero. If the stock adjustment $(Q_t^L - X_t)$ is greater than carryover from the last period, the quantity marketed is

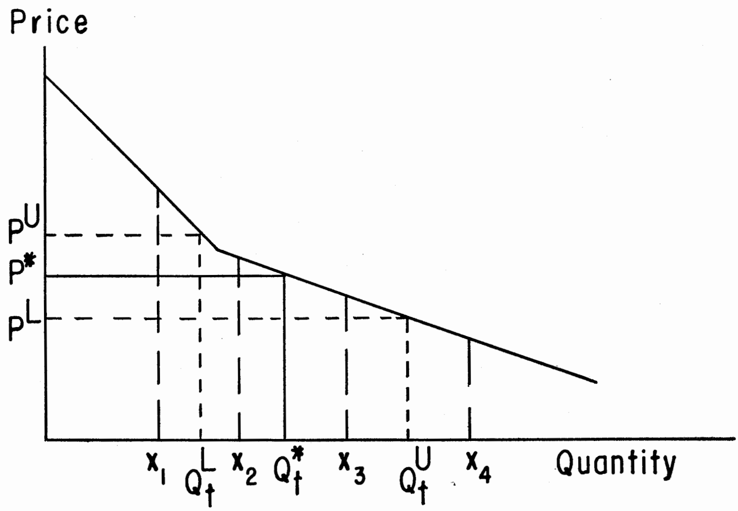

Figure 5. Static Example of the Operation of Model II

assumed to be $Q_t - X_t + C_{t-1}$ which will bring a price greater than P^U, and carryover into the next period will be zero.

When current production is between Q_t^L and Q_t^U $(X_t = x_2 \text{ or } x_3)$, the market operates without intervention, price is between P^U and P^L, and inventories remain at the same level. P^U and P^L are fixed at prescribed levels. But because of the stochastic and dynamic nature of the demand function, Q_t^U and Q_t^L are dependent on random and lagged values and hence are not the same for each period.

Notationally, the inventory policy operates according to the following rules:

1. If $[X_t < Q_t^L$ and $(Q_t^L - X_t) < C_{t-1}]$,

$$Q_t = X_t + (Q_t^L - X_t) = Q_t^L$$

$$P_t = P^U$$

$$C_t = C_{t-1} + (X_t - Q_t^L).$$

2. If $[X_t < Q_t^L$ and $(Q_t^L - X_t) \geqslant C_{t-1}]$,

$$Q_t = X_t + C_{t-1}, \qquad Q_t < Q_t^L$$

$$P_t \geqslant P^U$$
$$C_t = 0.$$

3. If $(Q_t^L \leqslant X_t \leqslant Q_t^U)$,

$$Q_t = X_t$$
$$P^U \leqslant P_t \leqslant P^L$$
$$C_t = C_{t-1}.$$

4. If $[X_t > Q^U$ and $C_{t-1} + (X_t - Q_t^U) \leqslant 1{,}000]$,

$$Q_t = X_t - (X_t - Q_t^U) = Q_t^U$$
$$P_t = P^L$$
$$C_t = C_{t-1} + (X_t - Q_t^U).$$

5. If $[X_t > Q_t^U$ and $C_{t-1} + (X_t - Q_t^U) \geqslant 1{,}000]$,

$$Q_t = X_t + (1{,}000 - C_{t-1}), \qquad (Q_t \geqslant Q_t^U)$$
$$P_t \leqslant P^L$$
$$C_t = 1{,}000.$$

The values chosen for P^U and P^L are arbitrary. For the actual simulation, several values were used, some which provided for a uniform range around the equilibrium price of 120, and some which provided for the purchasing price P^L to be closer than the selling price P^U to the equilibrium price. This latter situation could result if political pressure caused enforcement of policies which would call for supplies to be off the market when price dropped only slightly below a level considered desirable, but which prevented stocks from being sold except when price threatened to be exceedingly high. This would be a situation desirable to farmers, but could have undesirable consequences as discussed in a later section depicting simulation results.

Model III

The third model is designed to approximate and test the optimizing inventory rule given by a multistage dynamic programming model which minimized the present value of net social cost plus storage cost over time [for the complete model and results, see Kalbfleisch, 5]. Calculations revealed that total discounted expected losses over an infinite planning horizon are minimized by storing 85 percent of the amount by which total supply quantity exceeds 1550 million bushels. When the total supply quantity is less than 1550 million bushels, carryover is zero.

To test this rule under a broader range of conditions than was feasible with the dynamic programming model, Model III is programmed to operate as follows:

$$S_t = X_t + C_{t-1} \tag{16}$$

$$C_t = \begin{cases} \theta(S_t - Q^*), & S_t > Q^* \quad (Q^* = 1550) \\ 0 & , S_t \leq Q^* \end{cases} \tag{17}$$

$$Q_t = S_t - C_t, \tag{18}$$

where θ is the percentage of excess supply $(S_t - Q^*)$ which is to be carried over into the next period. Model III was run using several values for θ, ranging from .70 to 1.0.

Figure 6 gives a static, one-period example of the operation of Model III. Q is the aggregate demand curve for the three consuming sectors when $\varepsilon = 0$ and $QE_{t-1} = 795$, their expected values. If production in the current period (X_t) is 1475 and carryover from last period (C_{t-1}) is 775, then total supply (S_t) available for all uses, including stocks, is 2250 and the excess of total supply over normal equilibrium (Q^*) is 700. If θ is .85 so that 85 percent of this excess is stored, carryover will be 595, and 1655 will be marketed at a price of approximately 112. Thus

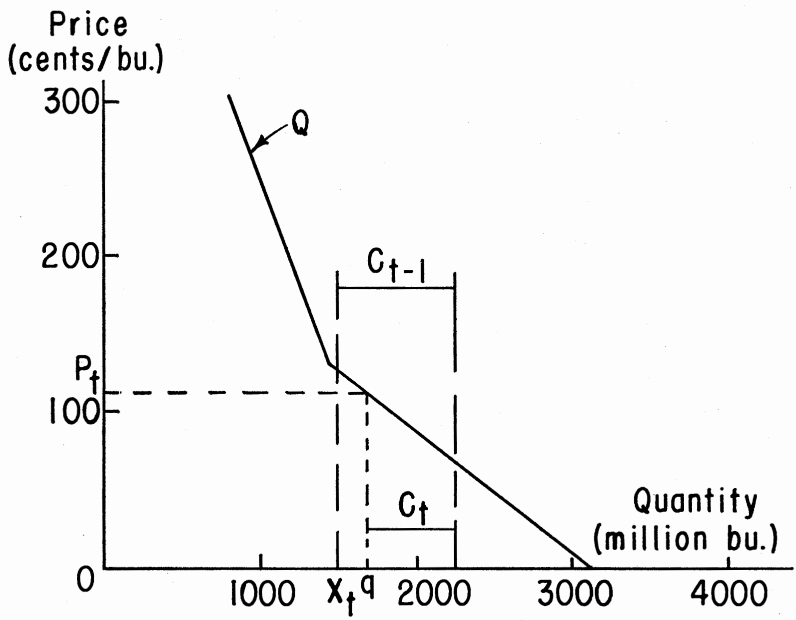

Figure 6. Static Example of the Operation of Model III

$S_t = X_t + C_{t-1} = 1475 + 775 = 2250.$
$C_t = \theta(S_t - Q^*) = .85\ (2250-1550) = 595$, and
$Q_t = S_t - C_t = 2250-595 = 1665.$

The above three models represent quite different approaches to wheat reserve management and require somewhat different methods to implement in actual practice. We now turn to the results obtained when each of the three carryover models is applied to the simulated wheat economy.

RESULTS FROM SIMULATING THE THREE BASIC MODELS

There is no single criterion by which to rate any given reserve management policy as the overall optimal or best. Policy makers base their choice of reserve management policy on several criteria including net social cost, and the mean and variance of prices, receipts, net income and production. Accordingly, a number of such variables are presented in this section from the simulated operation of the wheat economy under the three stock management models described earlier.

To make as many of these comparisons as meaningful as possible, the results considered significant from each basic model are presented. Results are then compared among the three basic models.

Model I Results

Inventory Model I, where stocks are determined by a function representing the private market, was simulated under the four different supply situations. The first situation considers supply to be market determined according to equation (7). The other three situations correspond to supply set autonomously as in equation (8), with C*, the desired or target carryover, set at 200, 400, and 600 million bushels. In the following discussion of the results, and in the accompanying tables, these four situations are designated as situations I_M, I_2, I_4, and I_6, respectively. The I_M situation is a free market in supply and demand, whereas the latter three situations are free market only in demand. Table 5 shows five summary measures on each of the twelve variables from 4000 simulated periods for the four situations.

Comparison of situations I_2, I_4, and I_6 demonstrates the effects of assuming that the demand for all components, including stocks, follows one functional form, dependent upon price, while supply is determined according to other considerations. Having supply and demand components determined according to different considerations does not cause a true disequilibrium condition to exist in the sense of price and quantity failing to tend toward stable average values, but the supply determi-

Table 5. Selected Model I Simulation Results: Means, Coefficients of Variation, Minimums and Maximums of Twelve Variables.

	Model					Model			
Variable[1]	I_M	I_2	I_4	I_6	Variable[1]	I_M	I_2	I_4	I_6
Acreage					Stocks				
Mean	62.4	55.6	62.1	68.9	Mean	396.6	360.6	396.4	428.3
Std. Dev.	3.3	2.5	2.3	2.1	Std. Dev.	57.6	62.5	58.6	52.8
Coef. of Var.	5.2	4.4	3.7	3.1	Coef. of Var.	14.5	17.3	14.8	12.3
Minimum	52.8	49.3	56.7	62.9	Minimum	126.6	115.9	150.1	196.6
Maximum	76.2	65.4	72.0	78.1	Maximum	556.1	516.9	532.8	576.9
Yield					Price				
Mean	25.0	25.0	25.0	25.0	Mean	120.8	129.6	120.9	113.0
Std. Dev.	2.0	2.0	2.0	2.0	Std. Dev.	14.1	15.4	14.4	13.0
Coef. of Var.	8.0	8.1	8.1	7.9	Coef. of Var.	11.7	11.9	11.9	11.5
Minimum	21.0	21.0	21.0	21.0	Minimum	81.8	91.4	87.5	76.7
Maximum	30.0	30.0	30.0	30.0	Maximum	186.9	189.6	181.2	169.8
Production					Net Income				
Mean	1,560	1,390	1,552	1,720	Mean	626.7	683.1	625.1	558.4
Std. Dev.	147	132	139	146	Std. Dev.	169.1	182.9	179.8	171.9
Coef. of Var.	9.4	9.5	9.0	8.5	Coef. of Var.	26.9	26.8	28.8	30.8
Minimum	1,108	1,098	1,197	1,321	Minimum	174.7	281.6	234.8	105.3
Maximum	2,278	1,836	2,013	2,135	Maximum	1,288.9	1,315.0	1,232.3	1,177.6
Food					Gross Income				
Mean	564.8	562.5	564.7	566.7	Mean	1,875.3	1,794.4	1,867.8	1,935.7
Std. Dev.	4.0	4.6	4.2	3.8	Std. Dev.	195.7	211.3	207.4	195.3
Coef. of Var.	.70	.81	.75	.68	Coef. of Var.	10.4	11.8	11.1	10.1
Minimum	548.3	547.6	549.7	552.5	Minimum	1,354.6	1,268.0	1,382.6	1,440.3
Maximum	574.6	572.2	573.1	575.8	Maximum	2,674.9	2,512.3	2,513.2	2,681.7
Feed					Social Cost				
Mean	203.8	154.9	204.4	258.2	Mean	17.3	41.9	15.0	55.1
Std. Dev.	88.8	67.2	89.9	103.7	Std. Dev.	26.6	38.5	23.8	59.5
Coef. of Var.	43.6	43.4	44.0	40.1	Coef. of Var.	153.7	92.0	158.4	108.0
Minimum	100.0	100.0	100.0	100.0	Minimum	0.0	0.0	0.0	0.0
Maximum	534.1	447.7	482.8	580.0	Maximum	276.5	425.0	186.7	299.6
Export					Total Loss				
Mean	792.0	672.9	783.5	895.8	Mean	76.8	96.0	74.5	119.4
Std. Dev.	119.3	108.7	118.2	122.3	Std. Dev.	28.3	34.6	24.8	64.6
Coef. of Var.	15.1	16.2	15.1	13.6	Coef. of Var.	36.8	36.0	33.4	54.1
Minimum	433.4	374.0	471.0	560.1	Minimum	34.9	43.7	35.2	34.5
Maximum	1,166.5	1,025.3	1,104.4	1,227.0	Maximum	308.4	442.4	219.6	373.0

[1] Units correspond to those given in Table 1.

nation for I_2 and I_6 cause new equilibriums to be established. To see why this is so, consider the expected value for supply each period:

$$E(S_t) = E(X_t + C_{t-1}) = E(A_t \cdot Y_t + C_{t-1})$$
$$= \frac{QP + C^* - C_{t-1}}{YP} \cdot E(Y_t) + C_{t-1},$$

and since $E(Y_t) = 25 = YP$,

$$E(S_t) = QP + C^* - C_{t-1} + C_{t-1}$$
$$= 1550 + C^*, \qquad (QP = 1550).$$

Then the expected supply when the desired carryover, C^*, is 200, 400, and 600 million is:

$$E(S_t^{200}) = 1750,$$
$$E(S_t^{400}) = 1950,$$
$$E(S_t^{600}) = 2150.$$

Only $E(S_t^{400})$ is consistent with the normal equilibrium price of 120 and total quantity of 1950 (1550 for the three consuming sectors plus 400 for stocks). In this case the desired carryover is also the expected value for stocks under the normal equilibrium values. The lower average quantity supplied must result in a higher average price and the greater quantity in a lower price. It is interesting to note that in the actual simulation, total supply averaged 1751, 1949, and 2149 for the three situations.

It is possible to use the elasticities of demand to roughly predict the price and sector allocations resulting from these quantity changes. An aggregate long-run price flexibility is about –.60 for values near equilibrium. This means that the new equilibrium price should be established about six percent lower in the case of quantity supplied being 10 percent higher, and six percent higher as the quantity supplied drops 10 percent to 1750. Average price actually increased 7.2 percent for situation I_2 and decreased 6.5 percent for situation I_6. Also, the change in exports of approximately 14 percent is consistent with the price changes of 7.2 and 6.5 percent and the long-run export demand elasticity of about –2.0. Similar comparisons are possible for the other demand sectors.

The situations represented by I_2 and I_6 are disequilibriums in the sense that acreage is always set as if to reach a carryover level that will not, on the average, be achieved. From the stock relationships $QS_t = 895 - 4.125P_t$ (this is appropriate because price never reached 200, the upper limit for this equation to apply), it is seen that the 200 million bushel average would be reached only with an average price of 168 cents while the 600 million bushel carryover requires an average price of 72 cents.

These situations could correspond to the events that could occur under a free selling market with an acreage quota set using incorrect demand estimates. For example, acreage might be set at a level consistent with believing that the market will demand 200 million bushels for inventory at an established "fair price" of 120 per bushel, but the industry wishes to stock 400 million bushels at this price, thus driving the market price higher. The consuming sectors use less at this higher price, and stocks are less than would be taken at the 120 price but greater than the 200 million bushels expected to be taken.

The income figures resulting from these situations are of interest. The lower quantity (higher price) equilibrium of situation I_2 causes net income to increase by 9.3 percent, as compared with situation I_4, while gross income decreases by 3.9 percent. The results are similar for the higher quantity (lower price) equilibrium of situation I_6 where net income is 10.7 percent less and gross income is 3.6 percent greater, again as compared with situation I_4. When the coefficient of variation is used as a measure of stability, higher incomes are associated with greater stability for both measures of income.

As average gross income increases from 1794 to 1868 to 1936 (for I_2, I_4, and I_6, respectively), the coefficient of variation decreases from 12 to 11 to 10 and the standard deviation also decreases from 211 to 207 to 195. As average net income increases from 558 to 625 to 683 (for I_6, I_4, and I_2), the coefficient of variation decreases from 31 to 29 to 27 but the standard deviation increases from 172 to 180 to 183. The range of net income, indicated by the maximum and minimum values, is slightly less for I_6 than for I_2.

Situations I_2 and I_6 both result in average social cost several times that of I_4, probably indicating that the "struggle" to reach an impossible equilibrium causes the quantity marketed to vary markedly from the equilibrium quantity.[1] When storage cost is added to calculate the total loss, approximately the same average absolute differences remain, but the relative differences average much less.

It is possible to compare the results of situations I_M and I_4 to show the responses resulting from acreage determined by the market (I_M) and autonomously (I_4). Both situations theoretically give the same expected price and quantity equilibriums so that the differences that show up must be caused either by random influences or by the different supply determination methods. Because the average price and quantity figures are very similar for the two situations, any substantial differences must be due mostly to the way in which acreage is set.

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[1] In the calculation of social cost for this model, the market demand function is the aggregate of the three consuming sectors, and the market supply function is that established earlier as the fixed "planning" supply function. The equilibrium quantity is established by the intersection of these curves, and the quantity utilized is calculated as $Q_t + X_t + C_{t-1} - C_t$ which is the quantity taken by the three consuming sectors. Thus the equilibrium quantity corresponds to that which must be established because of the acreage determination rule so that the figures given correctly calculate social cost as defined earlier.

Although there is no test to measure the statistical significance of differences among forms of Model I, most differences seem to be quite small. With acreage determined by the market, average acreage and social cost are higher, by variation in income is lower. There appears to be little advantage in intervening in production to obtain the desired supply if there is a free market on the demand side.

Model II Results

Model II, which provides for stocks to be used to maintain price within certain prescribed limits,[2] was simulated using the same four supply determination conditions as Model I. These situations are designated as II_M, II_2, II_4, and II_6 in the following discussion. Situation II_M is a free market in supply but not in demand.

As discussed earlier, the values for P^U and P^L, which establish the price range within which the market operates without reserve stock adjustments, were arbitrarily chosen. Table 6 shows the 12 different price range situations which were simulated. For situation 1, the range is actually zero so that inventory adjustments are used to force the equilibrium price to prevail whenever possible. Also, only situations 1, 6, 10, 11, and 12 are "equilibrium" situations in the sense that there is a uni-

[2] Or conversely, uses market price to indicate a potentially undesirable situation (shortage or surplus) that warrants prevention via an inventory adjustment.

Table 6. Twelve Model II Price Range Situations.

Situation	$P^U - P^L$	Spread	Spread From P*	
			P^U	P^L
		—cents per bushel—		
1[1]	120 - 120	0	0	0
2	125 - 120	5	5	0
3	130 - 120	10	10	0
4	140 - 120	20	20	0
5	150 - 120	30	30	0
6[1]	125 - 115	10	5	5
7	130 - 115	15	10	5
8	140 - 115	25	20	5
9	150 - 115	35	30	5
10[1]	130 - 110	20	10	10
11[1]	140 - 100	40	20	20
12[1]	150 - 90	60	30	30

[1] For situations 1, 6, 10, 11 and 12, P^U is the same amount above P* as P^L is below P*. These are referred to as the equilibrium situation of Model II. For the remaining situations, P^U is farther above P* than P^L is below P*. These are referred to as the disequilibrium situations of Model II.

form range around the assumed normal equilibrium price of 120. In the other seven situations, the "selling price," P^U, is further removed from the equilibrium price than is the "buying price", P^L. For situations 2, 3, 4, and 5, P^L is also the equilibrium price of 120, but P^U varies from 125 to 150. Thus P*, the equilibrium, normal or desired price, also acts as a floor below which price will not fall except when stocks reach an upper limit of 1000 as explained earlier.

The fact that Model II was simulated using twelve price ranges each under four supply determination conditions means that there are 48 different situations to consider and compare for Model II alone. This section reports only those results from the simulation runs which are economically significant and which show how this reserve stock management policy performs under various conditions. The first results presented consider only the "equilibrium" situations, 1, 6, 10, 11, and 12, simulated for 4000 periods, and show comparisons between results when acreage is market determined as opposed to results when acreage is autonomously determined.

Situations Having a Uniform Range Around P*

Table 7 shows the means and Table 8 the coefficients of variation for eight series under the four supply determination conditions. Table 9 shows the percentage occurrence of certain events with the model. As the price spread increases slightly from zero, reserves are used with some success to keep the quantity marketed fairly close to the equilibrium level (Table 7). But as the spread becomes greater, the quantity actually used is free to vary further from the assumed equilibrium, causing average social cost to increase. The fact that average total social loss decreases is directly connected to the average size of stocks held as the spread increases. The values shown for average stocks decrease as the range between P^U and P^L widens. This is largely a chance happening.

When stocks fell to zero (or a very low level), it was possible for this value to hold for many periods because the price spread was so wide that only seldom did production vary enough to cause an adjustment in reserves. This can be seen from Table 9 which shows, for example, that when P^U and P^L were 150 and 90 respectively, 28.9 percent of the time (37.1 – 8.2) inventories were zero but production was not sufficient to warrant adding anything to reserves according to the inventory policy being followed. When many of these low or zero values

Table 7. Selected Model II Simulation Results, Equilibrium Situations: Means of Eight Variables.

Situation[1] $(P^U - P^L)$	Model	Means[1] Acreage	Production	Price	Stocks	Net Income	Gross Income	Social Cost	Total Loss
1 (120-120)	II_M	62.3	1558	120.5	559	629	1875	21.3	105.2
	II_2	60.0	1502	121.6	249	626	1827	24.2	61.6
	II_4	61.0	1526	120.2	425	614	1834	26.3	90.0
	II_6	61.3	1534	119.8	617	612	1838	25.9	118.5
6 (125-115)	II_M	62.1	1553	120.3	541	620	1863	16.5	97.7
	II_2	60.2	1508	121.3	243	619	1824	24.1	60.7
	II_4	61.0	1526	120.2	426	609	1828	25.1	88.9
	II_6	61.1	1529	120.0	622	608	1830	24.6	117.9
10 (130-110)	II_M	62.1	1551	120.2	567	617	1859	15.8	100.8
	II_2	60.3	1509	121.2	243	614	1820	27.2	63.6
	II_4	60.8	1521	120.4	430	606	1822	27.0	91.6
	II_6	60.8	1522	120.4	630	606	1822	27.0	121.5
11 (140-100)	II_M	62.5	1561	120.9	232	624	1874	28.6	63.4
	II_2	62.6	1568	119.3	183	602	1855	32.2	59.7
	II_4	63.1	1582	118.5	371	594	1856	33.2	88.8
	II_6	63.2	1581	118.5	570	595	1859	33.7	119.2
12 (150- 90)	II_M	62.8	1571	121.6	79	633	1890	41.1	53.0
	II_2	65.1	1629	116.7	122	581	1884	45.3	63.7
	II_4	65.7	1646	115.7	305	572	1887	49.9	95.7
	II_6	65.9	1649	115.6	502	670	1889	52.0	127.3

[1] Situation numbers correspond to those given in Table 6.
[2] Units correspond to those in Table 1.

Table 8. Selected Model II Simulation Results, Equilibrium Situations: Coefficients of Variation of Eight Variables.

Situation[1] $(P^U - P^L)$	Model	Coefficients of Variation: Acreage	Production	Price	Stocks	Net Income	Gross Income	Social Cost	Total Loss
1 (120-120)	II_M	5.0	9.8	10.8	61.2	34.5	13.0	199.6	57.4
	II_2	12.2	14.6	5.9	73.9	27.7	15.4	137.3	82.1
	II_4	13.6	15.7	1.2	48.9	27.0	15.7	119.1	54.1
	II_6	13.5	15.6	1.1	33.6	27.3	15.7	115.3	36.2
6 (125-115)	II_M	4.6	9.4	9.6	65.6	28.8	11.0	247.0	66.2
	II_2	11.0	13.7	6.8	67.9	23.7	12.9	138.5	76.5
	II_4	12.1	14.5	3.8	43.4	21.8	12.8	128.3	51.5
	II_6	11.9	14.4	3.8	29.5	21.9	12.7	126.7	36.5
10 (130-110)	II_M	4.2	9.2	9.4	59.7	26.2	10.0	192.7	57.1
	II_2	9.8	12.8	8.5	60.8	22.9	11.3	137.2	72.8
	II_4	10.5	13.3	6.8	37.4	21.0	11.0	136.6	51.0
	II_6	10.5	13.3	6.8	25.5	21.0	11.0	136.6	38.3
11 (140-100)	II_M	5.5	9.8	14.5	96.8	34.1	12.1	193.0	96.1
	II_2	7.8	11.3	12.3	66.6	28.4	10.9	143.9	79.0
	II_4	8.3	11.7	11.2	35.8	26.4	10.2	143.9	55.6
	II_6	8.4	11.7	11.3	23.6	26.4	10.3	145.3	42.0
12 (150- 90)	II_M	6.0	10.0	17.8	140.4	41.0	13.8	157.6	123.5
	II_2	5.6	9.9	14.9	75.0	35.4	11.5	131.1	90.6
	II_4	6.3	10.3	14.0	34.5	33.9	10.9	131.7	66.1
	II_6	6.6	10.5	14.1	21.9	34.0	10.9	134.9	52.3

[1] Situation numbers correspond to those given in Table 6.

Table 9. Selected Model II Simulation Results, Equilibrium Situations: Percent Occurrence of Six Price-Related Events.

Situation[1] $(P^U - P^L)$	Model	Percentage Occurences Column Number[2] 1	2	3	4	5	6
1 (120-120)	II_M	8.6	8.6	75.7	75.7	15.7	0
	II_2	12.6	12.6	87.4	87.4	0	0
	II_4	2.4	2.4	97.6	97.6	0	0
	II_6	0	0	96.9	96.9	3.1	0
6 (125-115)	II_M	9.3	7.3	31.7	27.7	10.0	23.3
	II_2	9.4	6.3	32.4	34.0	0	27.3
	II_4	1.5	1.4	36.9	35.7	0	26.0
	II_6	0	0	38.0	34.6	1.5	26.0
10 (130-110)	II_M	5.4	3.1	23.0	19.8	6.1	48.0
	II_2	6.0	3.2	24.3	23.8	0	48.7
	II_4	0.3	0.2	26.9	24.4	0	48.5
	II_6	0	0	27.0	23.9	0.6	48.5
11 (140-100)	II_M	19.1	5.7	12.9	11.0	0.1	70.3
	II_2	7.4	2.5	13.8	11.3	0	72.4
	II_4	0.1	0.1	16.1	12.1	0	72.7
	II_6	0	0	16.2	12.1	0	71.7
12 (150- 90)	II_M	37.1	8.2	5.3	4.7	0	81.8
	II_2	7.9	2.1	6.2	5.4	0	86.3
	II_4	0	0	7.6	6.1	0	86.3
	II_6	0	0	7.6	6.1	0	86.3

[1] Situation numbers correspond to those given in Table 6.

[2]

Column Number	*Percentage of:*	*Column Number*	*Percentage of:*
1	Zero inventory	4	Price equal to P^L
2	Price greater than P^U	5	Price less than P^L
3	Price equal to P^U	6	Price between P^U and P^L

were encountered, the average value for stocks was naturally low. Since total loss includes a storage charge, total loss decreased as average stocks became very low.

When the coefficient of variation is used to measure variability, greater stability of all series is achieved when the upper and lower price limits are 130 and 100 respectively (Table 8). This is an indication that, according to the model, a price spread either way of 10 from the desired or equilibrium price provides for sufficient flexibility and size of stocks to maintain a reasonably stable marketing and production situation. This price range also resulted in less chance of zero inventory when acreage is market determined.

In situation II_M where acreage is market-determined by the distributed lag equation (7), not only is price dependent upon the level of production through the negative price coefficient of the demand function, but production is also directly dependent upon price through the positive relationship of acreage to price. In situations II_2, II_4, and II_6, acreage is not directly dependent upon price but on the deviation of actual carryover from desired carryover (equation 8).

When supply is determined autonomously by setting acreage at a level designed specifically to result in production sufficient to cover the predicted consumption needs of the current period plus a desired carryover (situations II_2, II_4, II_6), different responses are noted. Table 8 shows generally more variability in acreage and production and less variability in the price and income series for the three "controlled-supply" situations than for the market-supply situations. Tying acreage to the deviation of actual from desired carryover makes possible larger and more immediate adjustments in production. The result is a more orderly market in terms of price and income.

Why increasing the price spread results in lower price and inventory and in more production as seen in Table 7 is explained by Kalbfleisch [5, p. 92-94]. The income series for situations II_2, II_4, and II_6 show that increasing the price spread results in generally higher gross but lower net income. The changes are not great, net income falling about seven percent from high to low and gross income rising about three percent.

Average social cost is substantially greater in all three cases for wider price spreads as the quantity used deviates further, on the average, from the equilibrium quantity for the period. When social cost and storage cost are added to arrive at the total loss, the values are nearly the same for all price spreads because the higher social costs associated with the wider price range are just offset by lower storage costs from small reserve stocks.

Table 8 shows that for the three controlled supply situations a wider price spread results in greater stability for the acreage, production, stocks and gross income series; and less stable price, net income and total loss series.

For producers, both the level and stability of the income series, particularly net income, are probably most important. Tables 7 and 8 indicate that allowing acreage to be market determined results in higher but less stable income than having an outside force influence supply by setting acreage according to the specific rule employed. The market-determined acreage condition (situation II_M) also results in higher average total loss (social cost plus storage cost), an item that may be unimportant to producers but important to society in general.

Another item of importance is the performance of the reserve management policy in maintaining reserves. Under situations II_M and II_2, there is substantial chance of zero inventory and price being above the arbitrarily established limit even when the spread between P^U and P^L is fairly wide [5, p. 110]. Setting the target carryover between 400 and 600 nearly does away with this problem according to the simulated results.

By allowing supply as well as demand to be managed, reserves will be adequate in nearly all cases as long as the target carryover is at least 400 million bushels. The managed supply situations also provide some degree of income stability. But the desirable features of adequate reserves and stable incomes are purchased, in a sense, with slightly lower average incomes, undesirable to producers, and higher social cost, undesirable to society in general. The increased stability appears inadequate compensation to farmers for acreage controls – a government subsidy likely would be required.

Situations Having a Nonuniform Range Around P*

The seven simulated situations of Model II where the spread between P^U and P* is greater than between P^L and P* present additional problems in data reporting. These problems stem from the fact that these are not true equilibrium situations; therefore, some series can show continually increasing or decreasing tendencies so that the summary statistics do not stabilize. The results are not reported here but are available elsewhere [5, pp. 97-100].

Model III Results

Model III was designed to approximate and test the results of the dynamic programming analysis. It establishes carryover from one period to the next based on a proportion of the amount by which total supply exceeds the assumed equilibrium demand of 1550 million bushels. The wheat inventory model was formulated as a discrete, stochastic multi-stage decision suitable for optimization using the technique of dynamic programming. The output of the dynamic programming analysis is a conditional decision rule which establishes, for each possible level of supply, the carryover necessary to minimize an assumed total social loss function. The results indicate that total discounted net social loss over an infinite planning horizon is minimized if carryover into the next year is approximately 85 percent of the amount by which wheat production the current period plus carryover from the preceding period exceeds the equilibrium demand quantity.

Simulation Model III was run for the same four supply determination conditions as Models I and II. These four situations are designated as III_M, III_2, III_4, and III_6 in the following discussion. Five values were arbitrarily chosen for θ, the fraction which determines the portion of "excess supply" treated as carryover. The term "excess supply" refers here to the amount by which production plus carryover from the previous period exceeds 1550. If excess supply is found to be negative, it is treated as zero so that carryover into the next period is zero and the quantity marketed is the quantity produced in the current period. The five values chosen for θ are: 1.0, .90, .80, .75, and .70. When $\theta = 1.0$, the quantity marketed will always be the assumed equilibrium quantity of 1550 except when the carryover is zero as noted above. Price is not necessarily established at 120 when the quantity marketed is 1550 because of the random and dynamic characteristics of the demand function; for the same reason zero carryover does not require that price be above 120.

In Model II, additions to stock occur when X_t falls below a certain level, dependent on actual demand, and vice versa for withdrawals from stock. Adjustments to reserve stocks are not affected by current period demand conditions in Model III. Additions to stock occur only when the total available supply for period t is greater than for period t-1, and withdrawals when S_t is less than S_{t-1}.[3]

An inventory policy of this nature may lead to cycling or runs in the level of reserves, especially when θ is equal to or nearly equal to unity. To see why this possibility exists, consider a period t with unusually large production and sizeable carryover from period t-1. Assume that this causes S_t to exceed S_{t-1} so that there will be an addition to reserves as explained above $(C_t > C_{t-1})$. If $\theta = 1.0$, C_t will be large,

[3] Define SA_t to be adjustment in stocks during period t: $SA_t = C_t - C_{t-1}$. Then, $SA_t = C_t - C_{t-1} = \theta(S_t - Q^*) - \theta(S_{t-1} - Q^*)$; $SA_t = \theta(S_t - S_{t-1})$.
If $S_t > S_{t-1}$, then $SA_t > 0$ (an addition to stock, $C_t > C_{t-1}$).
If $S_t < S_{t-1}$, then $SA_t < 0$ (a withdrawal, $C_t < C_{t-1}$).

probably causing S_{t+1} to be even greater than S_t and resulting in another addition to stocks ($C_{t+1} > C_t$) which may in turn result in S_{t+2} being even larger, etc. Since the quantity marketed is still 1550 (if $\theta = 1$), there is no tendency for demand to change via the lagged variables. It may be difficult for this trend to be broken, but if random events do combine and result in a withdrawal, the reverse of the above procedure occurs and the stocks dissipate.

The possibility of a run or cycle exists only when acreage is determined via market conditions as in situation III_M and not if acreage is dependent on the deviation of actual from desired carryover as in situations III_2, III_4, and III_6. A trend cannot continue long in the latter situation because a larger carryover, for example, immediately reduces acreage and production, thus preventing an ever-increasing supply. An upward run can be broken in the market-determined acreage situation by a series of events, depending on the relative strength of the forces which have built up. For example, if demand in period t-1 was unusually low (a random event) so that the 1550 quantity marketed brought a very low price, acreage for period t will fall because of the lagged price coefficient in the acreage determination equation. If the random yield is also sufficiently low, S_t may be less than S_{t-1} (even though C_{t-1} was large) and the run will be reversed.

This problem did occur in the actual simulation for $\theta = 1.0$ in situation III_M. If stocks are limited to a maximum of 1000, the pattern seemed to be for stocks to reach 1000, then fall to zero and remain there. If an upper limit is not placed on stocks, the trend is generally upward and very large stocks accumulate. Because this cycling would probably not be allowed to occur in reality with the severity shown in the simulation, the results when $\theta = 1.0$ for situation III_M were considered unrealistic and are not reported here.

Means and coefficients of variation of nine selected variables for Model III are shown in Tables 10 and 11. The mean values shown in Table 10 follow fairly closely the pattern one would expect. For example, from Figure 6, it is apparent that Model III is not likely to give equilibrium results, on the average ($A = 62$, $P = 120$, $Q = 1550$, etc) except when $\theta = 1.0$. If θ is less than one, there is a definite bias toward smaller stocks and lower price and toward a larger quantity produced and consumed.[4] (See footnote number 4 at bottom of page 37.)

Smaller stocks associated with smaller values of θ can be explained: with the same excess supply conditions, a smaller θ requires that a smaller portion be held as reserve stock and a larger portion of the total available supply be marketed.

Price is biased downward because with average supply conditions, S_t will usually exceed 1550. With normal demand conditions, this must result in price less than 120 when θ is less than one. This lower price results in the quantity demand increasing via the negative coefficient for P_t in the demand function. This effect is partially offset in the longer run as demand increases through the positive coefficient for QE_{t-1}.

These effects require a sort of cooperation from supply so that the method of acreage determination affects which forces prevail. When acreage is tied to the deviation of actual from desired carryover, smaller θ resulting in low stock means that this deviation is most often positive and acreage and production are high. S_t will, on the average, be sizeable and price lower as previously discussed.

In the actual simulation for situations III_2, III_4, and III_6, prices fell substantially as θ decreased, indicating that the negative P_t coefficient coupled with greater production prevailed over the offsetting influence of an actually greater demand which would tend to keep price up. The high acreage and low price conditions are naturally more severe for the higher desired carryover situations because the deviation of actual from desired carryover is greater.

When acreage is determined according to market conditions (equation 7) as in situation III_M, the effects are somewhat different. Given that $\theta < 1$ causes a low price, according to equation (7) acreage the next period will decline, causing production and total supply to be less.

[4] For Model III, average quantity marketed and used by the three consuming sectors, $Q = Q_H + Q_F + Q_E$, is the same as average production so Q is not shown in the table. To see why these values are the same, consider S_t as acquisition $S_t = X_t + C_{t-1}$. But S_t also has a disposal counterpart: $S_t = Q_t + C_t$. Since the S_t values must be equal for each period, they must be equal as totals and means so that:

$$\bar{S} = \bar{X} + \frac{1}{N} \sum_{t=1}^{N} C_{t-1} = \bar{Q} + \frac{1}{N} \sum_{t=1}^{N} C_t$$

$$\bar{X} + \frac{C_o}{N} = \bar{Q} + \frac{C_N}{N}.$$

When N is large, the difference between the carryovers C_o in the initial period and C_N in period N, divided by N is negligible and $\bar{X} = \bar{Q}$.

Table 10. Selected Model III Simulation Results: Means of Nine Variables.

		Means[1]								
θ	Model	Acreage	Production	Supply	Price	Stocks	Net Income	Gross Income	Social Cost	Total Loss
1.00	III_M	---	---	---	---	---	---	---	---	---
	III_2	61.9	1547	1750	121.4	203	641	1878	3.5	33.9
	III_4	62.0	1550	1950	121.3	400	640	1880	2.6	62.6
	III_6	62.0	1550	2150	121.3	600	640	1880	2.6	92.5
.90	III_M	62.4	1560	1862	120.8	303	634	1882	11.8	57.2
	III_2	62.7	1567	1750	120.4	183	631	1884	4.4	31.8
	III_4	63.6	1590	1950	119.2	360	622	1893	4.8	58.8
	III_6	64.4	1610	2150	118.2	540	613	1901	7.4	88.4
.80	III_M	62.6	1563	1728	121.0	165	635	1887	14.4	39.1
	III_2	63.5	1587	1750	119.4	163	621	1891	7.0	31.5
	III_4	65.2	1630	1950	117.2	320	603	1907	11.9	59.9
	III_6	66.8	1670	2150	115.2	480	585	1920	22.4	94.4
.75	III_M	62.0	1550	1662	121.0	112	610	1850	16.7	33.5
	III_2	63.9	1597	1750	118.9	152	616	1894	9.0	32.0
	III_4	66.0	1650	1950	116.2	300	593	1913	17.4	62.4
	III_6	68.0	1700	2150	113.8	450	570	1930	33.8	101.3
.70	III_M	62.5	1558	1656	121.0	99	625	1875	18.8	33.6
	III_2	64.3	1607	1750	118.4	142	612	1897	11.4	32.8
	III_4	66.8	1670	1950	115.3	280	584	1919	24.0	66.0
	III_6	69.2	1730	2150	112.4	420	555	1938	47.9	110.9

[1] Units correspond to those given in Table 1.

Table 11. Selected Model III Simulation Results: Coefficients of Variation of Nine Variables.

θ	Model	Coefficients of Variation								
		Acreage	Production	Supply	Price	Stocks	Net Income	Gross Income	Social Cost	Total Loss
1.00	III_M	---	---	---	---	---	---	---	---	---
	III_2	7.9	11.1	7.4	12.6	59.1	43.9	16.6	341.9	59.8
	III_4	8.3	11.4	6.7	12.5	31.5	44.9	17.0	158.8	31.2
	III_6	8.3	11.4	6.1	12.5	21.0	44.9	17.0	158.8	21.2
.90	III_M	6.4	10.6	20.4	13.5	104.8	41.7	16.0	273.5	16.0
	III_2	7.2	10.6	7.4	12.5	59.6	42.0	15.3	293.9	15.3
	III_4	7.6	10.9	6.8	12.0	32.3	42.9	15.5	107.6	15.5
	III_6	7.6	10.9	6.2	11.8	21.8	43.1	15.3	94.0	15.3
.80	III_M	5.7	9.9	14.5	13.5	105.1	38.3	14.2	270.7	14.2
	III_2	6.4	10.2	7.5	12.6	60.2	40.5	14.2	218.3	14.2
	III_4	6.8	10.4	7.0	11.8	33.1	41.5	14.2	94.1	14.2
	III_6	6.8	10.3	6.4	11.5	22.5	42.1	14.0	73.7	14.0
.75	III_M	5.5	10.2	12.9	14.0	114.6	37.5	13.5	225.6	13.5
	III_2	6.4	10.2	7.6	12.7	60.5	40.0	13.8	189.2	13.8
	III_4	6.4	10.1	7.1	11.8	33.5	41.0	13.7	89.5	13.7
	III_6	6.3	10.1	6.6	11.5	23.0	42.0	13.4	68.3	13.4
.70	III_M	5.8	10.1	12.1	14.3	112.3	37.0	13.5	202.4	13.5
	III_2	5.7	9.7	7.6	12.8	60.7	39.6	13.4	166.2	13.4
	III_4	6.1	9.9	7.1	11.9	33.9	40.7	13.2	86.2	13.2
	III_6	5.9	9.9	6.7	11.5	23.4	42.1	12.9	64.9	12.9

In the actual simulation, this pressure seemed to be enough to keep price and acreage nearly the same for all values of θ. However, the low values for S_t associated with small values of θ meant that stocks were usually small and often zero. This is shown in Table 12 which gives the percentage occurrence of zero inventory for the 20 situations of Model III.

Estimates in Table 10 for the managed-supply situations III_2, III_4, and III_6 show that gross income is higher for smaller values of θ. But smaller values for θ result in lower net incomes due to the increased costs associated with larger acreages. Gross incomes are also higher when the desired carryover is larger, again indicating that the production component of total revenue outweighs the price component. And again, when the costs of producing additional acres are subtracted, net incomes are lower for the higher target carryover situations.

For the free market acreage situation III_M, the comparatively lower acreage (for each value of $\theta < 1$) gives lower gross income than for situations III_2, III_4, and III_6 in spite of the fact that for situation III_M price does not decrease with θ as it does in the managed-supply situations. This again shows the dominance of the production component in gross income. The lower acreage figures for situation III_M result in production costs which are enough lower to cause net income to be greater for III_2, III_4, and III_6.

The results pertaining to income may be summarized as follows:

1. High net income is associated with:
   a. θ large (close to 1.0).
   b. C* small.
2. High gross income is associated with:
   a. θ small,
   b. C* large.
3. Gross income is lowest for situation III_M.
4. Net income is highest for situation III_M.

Table 10 shows that average social cost for all four situations of Model III is higher for smaller θ. This result follows from the fact that

Table 12. Selected Model III Simulation Results: Percent Occurrence of Zero Inventory.

	Model			
θ	III_M	III_2	III_4	III_6
1.00	---	6.4	0	0
.90	21.6	6.5	0	0
.80	25.8	6.5	0	0
.75	32.2	6.5	0	0
.70	31.5	6.5	0	0

smaller θ cause less storage and the quantity marketed to be further removed from the assumed equilibrium for the period. Less storage results in lower storage costs for decreasing θ since storage cost is proportional to the storage level.

Figure 7 shows the relationships among social cost, storage cost and total cost for the four situations of Model III. In all four cases (and for θ decreasing), the decreasing storage cost and increasing social cost functions combine to give a total loss function that declines to a mini-

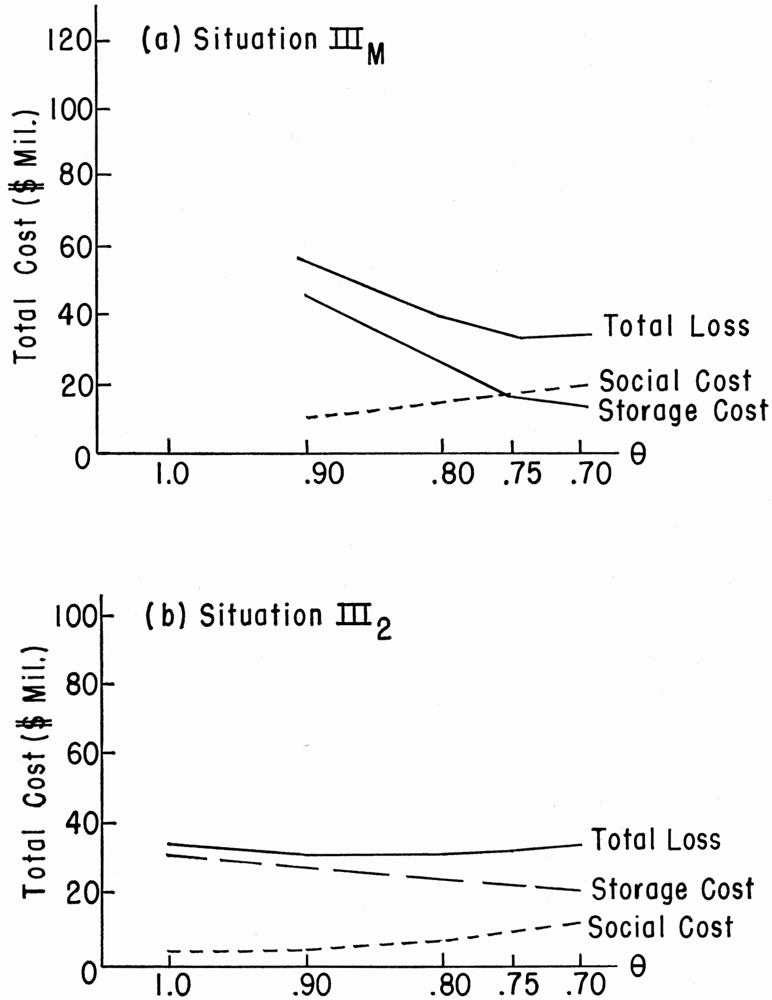
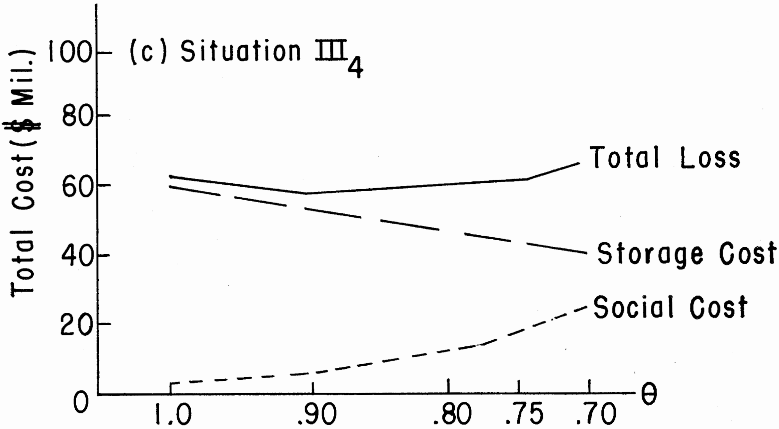


Figure 7. Social Cost, Storage Cost, and Total Social Loss, Model III



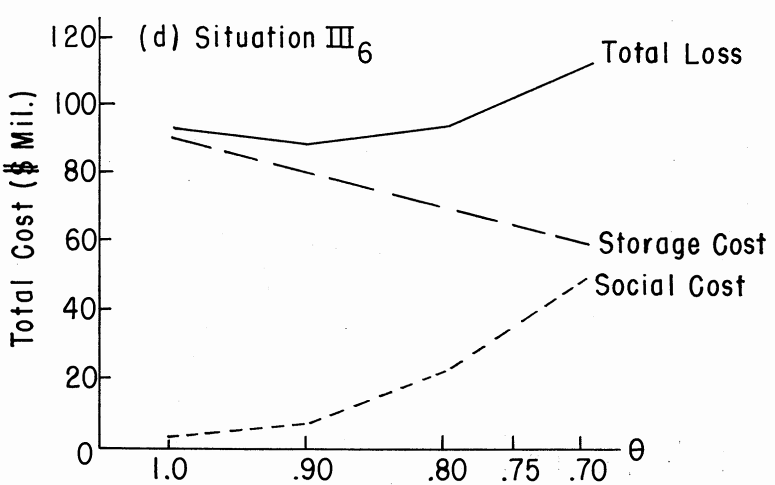


Figure 7. Continued.

mum, then increases. Table 10 and Figure 7 also show that both social costs and storage costs are higher for larger values of C* with the absolute differences greater for storage than social costs. The total loss for situation III_M falls generally between those of III_2 and III_4.

The minimum points on the total functions for III_2 and III_4 where acreage is tied to carryover seem to come reasonably close to the 85 percent point specified by the dynamic programming inventory model. The minimum for situation III_M is nearer 75 percent and for III_6 is nearer 90 percent. Moving rightward toward lower θ in Figure 7, storage cost decreases more rapidly and social cost increases less rapidly for situation III_M than for situations III_2, III_4, and III_6. Both of these conditions cause the minimum of total loss to be associated with smaller θ, and both conditions result from the dynamic interactions of jointly determined demand and supply through the acreage equation.

A weakness of the dynamic programming inventory model, as formulated, is that it does not include either market or autonomous acreage determination within the model. Thus the simulation results are an improvement. Based on total social loss, the 85 percent value for θ is too high. The value should be closer to 75 percent if acreage determination is left to market forces. The value could be 75 to 95 percent if acreage is set autonomously to provide a target carryover of 400 million bushels of wheat. While the total loss is less with a 200 than 400 carryover, the latter may be preferred because of less chance for zero inventories.

The low total loss and low variation in price and income suggest that a type III model can operate fairly well with autonomous (government) carryover decisions coupled with free market acreage determination. The high probability of zero inventory when acreage is market-determined severely detracts from the other promising features of III_M.

Comparison of Models I, II, and III

We now compare the various reserve management policies based on the results from the simulation of Models I, II, and III. The models are compared on the basis of variables considered most important: price, net and gross income, reserve stocks, social cost and total loss. For comparison of stability, the coefficients of variation of six variables are shown: acreage, production, price, net and gross income, and reserve stocks. Also, the performance of each model is appraised with respect to the likelihood of inadequate reserves — zero inventory.

The Free Market Acreage Situations

Looking first only at the situations where acreage is determined according to market conditions as in equation (7), some of the variables show sizeable differences among the means while for other variables there are hardly any differences (Table 13).

For the income variables alone, no model is consistently best. Both the highest and lowest net and gross incomes are associated with disequilibrium situations of Model II, but if the disequilibrium situations are not considered, both the highest and lowest incomes are found in Model III.

Social cost for I falls within the ranges of both II and III with the highest social cost coming in II when the price spread is widest and in

Table 13. Comparisons Among Models I, II, and III, Acreage Market-Determined.

		Means[1]						Coefficients of Variation					
Model		Price	Net Income	Gross Income	Social Cost	Total Loss	Stocks	Acres	Production	Price	Net Income	Gross Income	Stocks
I		120.8	627	1875	17.3	76.8	397	5.2	9.4	11.7	26.9	10.4	14.5
	Situation[2]												
	1	120.5	629	1875	21.3	105.2	559	5.0	9.8	10.8	34.5	13.0	61.2
	6	120.3	620	1863	16.5	97.7	541	4.6	9.4	9.6	28.8	11.0	65.6
II	10	120.2	617	1859	15.8	100.8	567	4.2	9.2	9.4	26.2	10.0	59.7
	11	120.9	624	1874	28.6	63.4	232	5.5	9.8	14.5	34.1	12.1	96.8
	12	121.6	633	1890	41.1	53.0	79	6.0	10.0	17.8	41.1	13.8	140.4
	2	122.5	651	1919	31.1	135.8	698	6.7	10.6	17.4	44.8	15.7	45.3
	3	118.0	577	1797	26.5	166.6	934	4.1	10.6	10.5	28.7	10.5	11.7
II	4	122.8	665	1936	22.4	163.9	943	3.8	9.7	10.3	27.1	10.0	8.2
	5	121.6	664	1927	28.0	172.7	965	3.9	9.4	13.4	27.6	9.5	7.5
	7	120.5	626	1870	15.7	136.9	808	3.6	8.4	8.5	23.3	8.7	46.4
	8	120.4	629	1876	17.9	146.1	855	2.5	9.4	7.4	18.8	6.5	23.4
	9	122.0	652	1918	21.1	165.4	962	3.2	10.2	8.9	22.1	7.7	18.2
	θ												
	1.00	---	---	---	---	---	---	---	---	---	---	---	---
	.90	120.8	634	1882	11.8	57.2	303	6.4	10.6	13.5	41.7	16.0	104.8
III	.80	121.0	635	1887	14.4	39.1	165	5.7	9.9	13.5	38.3	14.2	105.1
	.75	120.0	610	1850	16.7	33.5	112	5.5	10.2	14.0	37.5	13.5	114.6
	.70	121.0	625	1875	18.8	33.6	99	5.8	10.1	14.3	37.0	13.5	112.3

[1] Units correspond to those given in Table 1.
[2] Situation numbers correspond to those given in Table 6.

III when θ is smallest. When storage costs are added to social costs to give total social losses, Model III values are clearly lowest. Total loss is high in the disequilibrium situations of II because of the accumulation of stocks. The advantages of low total loss for Model III, due primarily to low storage costs, are largely offset by the high likelihood of reserve stocks being inadequate as shown in Table 14.

The coefficients of variation given in Table 13 generally show less stable conditions for all variables for Model III than for Models I and II. It is interesting to note that if the disequilibrium situations of Model II are not considered, situation 10 of Model II (when $\overset{U}{P} = 130$, $\overset{L}{P} = 110$) gives the greatest stability for all variables except stocks. When the disequilibrium cases are considered, greatest stability is achieved for all variables except production and stocks when $\overset{U}{P}$ is 140 and $\overset{L}{P}$ is 115 as in situation 8 of Model II. Such a situation could arise when an equal interval of price intervention is established around an "erroneous" equilibrium price of 127. The results suggest that such an error would not bring unfavorable consequences, whereas failure to properly estimate the equilibrium supply in Model III could cause severe imbalances.

A subjective ranking could select situation 10 as being the "best" of Model II situations based on overall low variability and low social

Table 14. Percent Occurrence of Zero Inventory, Models I, II, and III.

Model		Supply Situation MKT	200	400	600
I		0.	0.	0.	0.
	Situation				
II	1	8.6	12.6	2.4	0
	6	9.3	9.4	1.5	0
	10	5.8	6.0	1.3	0
	11	19.1	7.4	1.1	0
	12	37.1	7.9	0	0
	Situation				
II	2	4.0	6.0	0	0
	3	0	0	0	0
	4	0	0	0	0
	5	0	0	0	0
	7	0	0	0	0
	8	0	0	0	0
	9	0	0	0	0
	θ				
III	1.00	---	---	---	---
	.90	21.6	6.4	0	0
	.80	25.8	6.5	0	0
	.75	37.2	6.5	0	0
	.70	31.5	6.5	0	0

cost even though it shows neither best nor worst income or total loss levels. Comparing I with II (situation 10), shows the latter slightly more stable, except for stocks, and having more desirable income levels but less desirable social cost and total loss levels. Comparing II (10) to III ($\theta = .80$), shows II more stable but with lower net and gross incomes and higher total loss. If supply is market determined, there appear to be relatively few advantages in autonomous (non-market) determination of inventories.

The Controlled Acreage Situations

Comparisons among the means of the six variables for the three major models show some interesting results when acreage is set autonomously aiming for a particular carryover level each period (Table 15, 16 and 17). Many of the desirable results are associated with Model III and many of the undesirable results are associated with Model II — when the disequilibrium situations are not considered.[5] The "desired" high price and net income and low social cost and total loss of Model III are generally associated with the higher θ. However, gross income is highest in each table when $\theta = .70$, the smallest value. One exception to the desirability of Model III — if desirability of a model is measured by averages — is that when C* is 200, Model I gives the greatest average price and net income (but also results in the lowest gross income and total loss). The undesirable results associated with Model II come when the price spread is widest — $P^U = 150$, $P^L = 90$.

Consideration of Model II's disequilibrium situations show that situation 5 has nearly all of both the most and least desirable properties. II (5) has a wide upper and a zero lower price range ($P^U = 150$, $P^L = 120$) around the equilibrium price so that stock additions tend to exceed stock withdrawals. This situation consistently gives high prices and net incomes; but gives low gross income, high social cost, and consistently high total loss.

The coefficients of variation for the three models when acreage is tied to carryover[6] are given also in Tables 15, 16, and 17. Model III shows relatively very unstable income conditions, especially for the $\theta = 1.0$ situation. It should be noted that this is the same situation for

[5] Because these disequilibrium situations were simulated for only 55 periods, it is possible that the resulting values are not expected values so that comparisons to other situations might not be valid.

[6] Although relative stability does not seem to be influenced by the value of C*, the general stability conditions are considerably different than when acreage is market-determined. For example, under the market-determined acreage conditions, situation 10 of Model II gives the lowest coefficient of variation for five of the six variables considered, but excells in stability only for the income variables when acreage is set outside the market (again ignoring the disequilibrium situations of Model II).

Table 15. Comparisons Among Models I, II, and III, Desired Carryover 200 Million Bushels.

Model		Means[1]						Coefficients of Variation					
		Price	Net Income	Gross Income	Social Cost	Total Loss	Stocks	Acres	Production	Price	Net Income	Gross Income	Stocks
I		129.6	683	1794	41.9	96.0	361	4.4	9.5	11.9	26.8	11.8	17.3
	Situation[2]												
	1	121.6	626	1827	24.2	61.6	243	12.2	14.6	5.9	27.7	15.4	73.9
	6	121.3	619	1824	24.1	60.7	243	11.0	13.7	6.8	23.7	12.9	67.9
II	10	121.2	614	1820	27.2	63.6	243	9.8	12.8	8.5	22.9	11.3	60.8
	11	119.3	602	1855	32.2	59.7	183	7.8	11.3	12.3	28.4	10.9	66.6
	12	116.7	581	1884	45.3	63.7	122	5.6	9.9	14.9	35.4	11.5	75.0
	2	122.6	631	1839	13.8	50.1	242	9.2	11.6	2.1	19.3	10.3	57.1
	3	124.4	640	1809	22.8	66.5	291	8.9	11.3	3.8	17.6	9.2	44.5
	4	128.1	665	1791	36.7	88.5	344	8.5	10.9	6.9	17.5	8.2	34.6
	5	131.5	684	1771	55.2	114.3	394	8.2	10.5	9.6	20.2	8.6	28.1
II	7	122.1	627	1837	15.9	51.7	238	8.0	10.5	5.3	17.7	7.9	50.6
	8	124.9	647	1823	21.5	63.8	282	7.5	9.9	7.7	18.4	7.4	39.1
	9	127.8	666	1807	32.1	80.9	325	7.2	9.4	10.2	21.6	8.3	31.3
	θ												
	1.00	121.4	641	1878	3.5	33.9	203	7.9	11.1	12.6	43.9	16.6	59.1
	.90	120.4	631	1884	4.4	31.8	183	7.2	10.6	12.5	42.0	15.3	59.6
	.80	119.4	621	1891	7.0	31.5	163	6.4	10.2	12.6	40.5	14.2	60.2
III	.75	118.9	616	1894	9.0	32.0	152	6.0	9.9	12.7	40.0	13.8	60.5
	.70	118.4	612	1897	11.4	32.8	142	5.7	9.7	12.8	39.6	13.4	60.7

[1] Units correspond to those given in Table 1.
[2] Situation numbers correspond to those given in Table 6.

Table 16. Comparisons Among Models I, II, and III, Desired Carryover 400 Million Bushels.

		Means[1]						Coefficients of Variation					
Model		Price	Net Income	Gross Income	Social Cost	Total Loss	Stocks	Acres	Production	Price	Net Income	Gross Income	Stocks
I		120.9	625	1868	15.0	74.5	396	3.7	9.0	11.9	28.8	11.1	14.8
	Situation[2]												
	1	120.2	614	1834	26.3	90.0	425	13.6	15.7	1.2	27.0	15.7	48.9
	6	120.2	609	1828	25.1	88.9	426	12.1	14.5	3.8	21.8	12.8	43.4
	10	120.4	606	1822	27.0	91.6	430	10.5	13.3	6.8	21.0	11.0	37.4
II	11	118.5	594	1856	33.2	88.8	371	8.3	11.7	11.2	26.4	10.2	35.8
	12	115.7	572	1887	49.9	95.7	305	6.3	10.3	14.0	33.9	10.9	34.5
	2	122.1	630	1840	13.8	79.7	440	9.4	11.8	1.9	19.9	10.6	32.0
	3	124.4	640	1809	27.8	96.5	491	8.9	11.3	3.8	17.6	9.2	26.4
	4	128.1	665	1791	36.7	118.4	544	8.5	10.9	6.9	17.5	8.2	21.9
II	5	131.5	684	1171	55.2	144.3	593	8.2	10.5	9.6	20.2	8.6	18.6
	7	122.1	627	1837	15.9	81.7	438	8.0	10.5	5.3	17.7	7.9	27.5
	8	124.9	647	1323	21.5	93.8	482	7.5	9.9	7.7	18.4	7.4	22.9
	9	127.8	666	1807	32.1	110.9	525	7.2	9.4	10.2	21.6	8.3	19.4
	θ												
	1.00	121.3	640	1880	2.6	62.6	400	8.3	11.4	12.5	44.9	17.0	31.5
	.90	119.2	622	1893	4.8	58.8	360	7.6	10.9	12.0	42.9	15.5	32.3
III	.80	117.2	603	1907	11.9	59.9	328	6.8	10.4	11.8	41.5	14.2	33.1
	.75	116.2	593	1913	17.4	62.4	300	6.4	10.1	11.8	41.0	13.7	33.5
	.70	115.3	584	1919	24.0	66.0	280	6.1	9.9	11.9	40.7	13.2	33.9

[1] Units correspond to those given in Table 1.
[2] Situation numbers correspond to those given in Table 6.

Table 17. Comparisons Among Models I, II, and III, Desired Carryover 600 Million Bushels.

Model		Means[1]						Coefficients of Variation					
		Price	Net Income	Gross Income	Social Cost	Total Loss	Stocks	Acres	Production	Price	Net Income	Gross Income	Stocks
I		113.0	558	1936	55.1	119.4	428	3.1	8.5	11.5	30.8	10.1	12.3
	Situation[2]												
	1	119.8	612	1838	25.9	118.5	617	13.5	15.6	1.1	27.3	15.7	33.6
	6	120.0	608	1830	24.6	117.9	622	11.9	14.4	3.8	21.9	12.7	29.5
II	10	120.4	606	1822	27.0	121.5	630	10.5	13.3	6.8	21.0	11.0	25.5
	11	118.5	595	1859	33.7	119.2	570	8.4	11.7	11.3	26.4	10.3	23.6
	12	115.6	570	1889	52.0	127.3	502	6.6	10.5	14.1	34.0	10.9	21.9
	2	122.1	630	1840	13.6	109.6	640	9.3	11.8	2.0	19.9	10.6	21.9
	3	124.3	640	1810	21.9	125.4	689	8.7	11.1	3.8	17.6	9.0	18.3
	4	128.0	665	1794	34.8	145.9	741	8.1	10.5	7.0	17.7	8.0	15.2
II	5	131.2	684	1775	51.6	169.9	758	7.4	9.9	9.8	20.7	8.3	12.7
	7	122.1	627	1837	15.9	111.7	638	8.0	10.5	5.3	17.7	7.9	18.8
	8	124.9	647	1823	21.5	123.8	682	7.5	9.9	7.7	18.4	7.4	16.0
	9	127.8	666	1807	32.1	140.9	725	7.1	9.4	10.2	21.6	8.3	14.0
	θ												
	1.00	121.3	640	1880	2.6	92.5	600	8.3	11.4	12.5	44.9	17.0	21.0
	.90	118.2	613	1901	7.4	88.4	540	7.6	10.9	11.8	43.1	15.3	21.8
	.80	115.2	585	1920	22.4	94.4	480	6.8	10.3	11.5	42.1	14.0	22.5
III	.75	113.0	570	1930	33.8	101.3	450	6.3	10.1	11.5	42.0	13.4	23.0
	.70	112.4	555	1938	47.9	110.9	420	5.9	9.9	11.5	42.1	12.9	23.4

[1] Units correspond to those given in Table 1.
[2] Situation numbers correspond to those given in Table 6.

which level of net income and social cost are most desirable. Model I clearly shows a more stable production situation; the coefficients of variation for acreage and production are significantly lower for I than for II and III. This may be desirable, since acreage and production adjustments entail expenses that are not fully recognized in the simulation model. But the results show that a reserve management policy which puts a high premium on production stability may sacrifice some of the level or stability of income or the ability of the program to maintain adequate reserves.

As can be expected, price is both most and least stable for Model II, with the greatest variability associated with the large price spread situations. Models I and III provide similar price stability, generally about the same variation as the wide-price-range situations of Model II. It should be noted that Model II represents a "managed stock policy" in which private trade groups carry no stock for profit. However, the fact that private interests would actually perform some stocking operations means that the variability of the price and income series for the wide-price-range situations are overstated in Table 15 to 17.

A situation with certain favorable features may be selected from Models II and III for comparisons with I. For III, the situation when θ is .90 shows reasonably good characteristics, generally representing a compromise between more desirable mean values of income and social cost but less desirable stability than for $\theta = 1.0$ and the opposite for $\theta = .80$. Model II (10) is a similar compromise: stability is generally good and sacrifices in income levels, social cost and total loss are not great.

Comparing I with II, situation 10, shows I preferred for net income levels and a more stable production situation. Situation II (10) shows a higher gross income, considerably lower social cost and total loss, and slightly more stable net income. Comparing I with III, $\theta = .90$, shows I with a more stable production situation and greater and more stable net income. Model III has higher gross income and much lower social cost and total loss. Other differences are not great. The same comparisons between II and III shows III to be preferred in all cases with the notable exception that price and income are considerably less stable than for II.

Summary

This section has presented selected results from simulated reserve management policies presented by the three basic models. Several variations were considered for two of the models, and summary measures were calculated for a number of variables.

It is apparent that the models do not react alike with respect to supply conditions. For example, when acreage is set each period at a level designed to achieve a certain carryover level, Models I and III are quite sensitive to the target carryover used, but Model II is not. Also, whether acreage is tied to carryover or to price has more effect on the performance of the systems represented by Models I and II than for that represented by Models III.

This section does not attempt to summarize all the results from the many situations considered: a summary discussion of the results and implications of the simulation analysis is given later.

SENSITIVITY ANALYSIS

Given that specification or observation errors exist within the model, some measure of the potential seriousness of these errors can be obtained by resimulating the system using new parameter estimates. In particular, three separate changes were made in the model parameters and relationships that were previously assumed fixed.

Emphasis is on the export demand function because this is the most volatile and difficult to measure accurately of all the demand components. Also, this demand is most likely to shift over time: a functional representation that holds true today is likely to be in error at any future time. One change assumes a new level of export demand, the second a new slope of the export demand curve while retaining the same level of demand at the 120 equilibrium price. The third change entails an alternative acreage determination technique: acreage is fixed at the assumed equilibrium value of 62 million acres for each period.

The first change moves the export demand curve to the left so that the new equilibrium quantity for exports is 600. Since no offsetting shifts are made in other demand curves or the supply curve, a new aggregate demand function results which establishes new equilibrium values of 111 for price and 1436 for quantity.

The second change in the model entails a new slope parameter for the export demand curve while preserving all original equilibrium values. Again there are no offsetting shifts in the other demand functions so that another new aggregate demand function is formed. In equilibrium, the export demand short-run elasticity is increased from –.5 to –2.0 and the long-run elasticity from –2.0 to –6.0. This change is made for two reasons: (a) to see how the model and the system react to a quite radical change in the elasticity of an important demand component, and (b) because it is quite possible that the previously assumed values are too low, and may in fact be as great as the new values.

The third change in the model fixes the acreage at the previously assumed equilibrium value of 62. The change represents a new supply management philosophy, and allows the simulation results to be examined as if the acreage decision were not based on values generated by the model. This sensitivity analysis shows the ability of the system to cope with a static acreage. Now all upsets to the system, such as unusual demand or yield conditions, must be handled entirely by systematic adjustments in the demand quantity and price.

In short, the sensitivity analysis indicates that: (a) a shift in wheat demand represented by a horizontal movement of the export demand curve to the left markedly reduces average farm prices and incomes, (b) a change in wheat demand represented by increased demand elasticity gives a more stable system, and (c) if acreage were the same each year, wheat prices and incomes would be less stable [5, pp. 137-160].

The results show that some measures used in this study are sensitive to internal parameter values and that the nature of the sensitivity depends on the type of parameter involved. A shift in the demand curve affects nearly all values in the same manner so that those models or situations showing desirable properties still do so. On the other hand, the change in the demand curve slope is somewhat more selective because increased stability also lowers social cost and total social loss. This change would alter the choice of the best θ when total social loss is the criterion and when acreage is market determined. A change of the third type, fixing acreage, is similar to the second in that the total social loss function is not U-shaped. Nevertheless, those decision rules or situations previously reported as most favorable still retain these overall characteristics.

The change in net income with a new export demand equation is not very sensitive to the value used to represent variable production costs. Experiments conducted while the model was in the development stage seem to indicate that a 50 percent error in choosing the cost of production per acre would result in a net income error of less than 20 percent.

SUMMARY AND CONCLUSIONS

Three basic models to manage wheat reserves were developed and simulated under a number of demand and supply conditions. The models represent quite different reserve management policies and require different methods of implementation.

Changing from present policy to that represented by Model I requires that the Commodity Credit Corporation no longer deal in stocks —at least not in stocks held for policy purposes of achieving a desired level and stability of farm income and prices. Some agency such as the

CCC could continue to purchase quantities for foreign and domestic food aid programs. These quantities would be considered a part of normal demand and would not affect inventory management which Model I assumes is left to private interests within the grain trade industry. Price and income policy goals could still be achieved through government run production controls and direct payments, but not through purchases and sales of wheat stocks.

Model II and III require public intervention at least on the demand side of the market. Model II uses price to indicate situations where a public agency such as the CCC, acting according to previously set and publicized rules, is required to enter the market to buy or sell stocks in sufficient quantities so that market price remains within preset boundaries.

Implementing Model III would require a public agency to intervene whenever quantity relationships dictate. Reserve stocks would necessarily be publicly controlled (but not necessarily publicly owned), with additions made to these stocks during years in which the total available supply exceeds that of the preceding year and withdrawals made whenever supply is less than that of the preceding year. Withdrawals or additions could be made throughout the marketing year, with stock adjustment rates corrected to reflect the most recent supply estimates available.

As with Model I, food aid purchases under Models II and III would be a component of normal demand, and operation of the inventory policy need not be affected by methods, such as production controls and direct payments, designed to achieve other policy goals. A resume of the simulation analysis is provided below.

Model I

For inventory Model I, stocks are considered a free market component of total demand, with quantity inversely related to price. Four hundred million bushels will be carried over into the next period when the price is equal to the assumed equilibrium price of $1.20 per bushel. The simulation results show that the values of key economic variables are quite sensitive to the target carryover value if acreage is set autonomously. When this target carryover is less than 400 million bushels, acreage, production and gross income are low; while price, social cost and total social loss are high. The opposite relationships hold when the target carryover is more than 400 million bushels, except that social cost and total loss (social plus storage cost) are higher than when the target carryover is 400 million bushels.

If the reserve stock management is left to market forces, and acreage is set autonomously, then a target carryover of 400 million bushels, with acreage set to achieve that carryover level, appears to be a policy with several advantages based on measures used in this study. However, the gains from having acreage set autonomously rather than by market forces appear to be small, based on Model I, if there is a free market on the demand side.

Model II

Model II represents a managed inventory policy which uses price as a key to indicate whether reserve stock adjustments should be made. For the Model II situations which attempt to maintain a uniform price range around the assumed equilibrium price, the method of supply determination has considerable effect on the simulated results. When acreage is determined by market forces, situation 10 (where the upper price limit is $1.30 per bushel and the lower price is $1.10 per bushel) shows the lowest social cost but also the lowest net and gross income. Model II is not very sensitive to values chosen for C*, the target carryover value, for those situations where acreage is set autonomously. The income and social cost figures are generally less favorable, net income and price are more stable, and gross income and production conditions less stable for the controlled acreage situations than for the market determined acreage situations. The greater stability in wheat prices and incomes and lower total loss (social plus storage cost) are major advantages of autonomously determined acreage.

When the range around P* is not uniform — when the upper price limit (stock-selling price) is further above the equilibrium price than the lower price limit (stock-buying price) is below the desired or equilibrium price — there are biases toward large stocks and toward high prices. The stock bias is small when acreage is tied to the carryover level, and the bias towards high prices is not severe when acreage is tied to price. Production, stocks and gross income are higher when acreage is tied to price; while price, net income and social cost are higher when acreage is set autonomously. As long as the price range is not too severely one-sided and the limits are at least 10 cents above or below P*, then the income, social cost, and total loss values and stability conditions compare favorably with those occurring when the price range is uniform. Model II is a fairly "robust" procedure, not highly sensitive to mistakes in chosing P* as long as P^U or P^L does not get too close to P*.

If an inventory policy of the type represented by Model II is selected, a subjective evaluation of measures used in this study indicates that the most favorable overall results would be obtained by (1) setting acreage each year to achieve a 400 million bushel carryover, and (2) setting the upper and lower price limits at least ten cents per bushel above and below the equilibrium price.

Model III

Model III represents a managed inventory policy in which the excess of total available supply – production the current period plus carryover from the preceding period – over an equilibrium quantity of 1,550 million bushels determines the carryover level.

The results show that most summary measures are at least slightly sensitive to the value chosen for θ, the fraction of excess supply which is to be treated as carryover, and quite sensitive to the value of C^*, the desired carryover for those situations where acreage is autonomously set and is tied to the size of the deviation of actual from desired carryover. A large value of θ gives comparatively high net income and large stocks but low gross income, low social cost and generally less stable conditions. Larger C^* give higher gross income, social cost, total loss and stock levels, but lower net income. Tying acreage to price gives greater gross but smaller net income than when acreage is tied to carryover.

Model III was designed to test the inventory policy from the dynamic programming analysis which indicated that a θ value of .85 minimized total loss. The simulation results concur with this result for the controlled acreage situations. But $\theta = .75$ appears to be more nearly optimal for the market-determined acreage situations. Social cost and total loss are affected more by the supply determination condition than by the choice of θ.

A reserve management policy of the type represented by Model III would require that acreage be set outside the market to prevent an intolerably high probability of no reserves or zero inventory. Within the managed supply situations reported, a value of .80 for θ with a target carryover of 400 million bushels has several advantages based on measures used in this study.

Model Comparisons

It is difficult, for several reasons, to judge which model gives the best overall performance. First, no reserve management policy rates consistently best for all conditions and criteria. Second, there is no criterion without weakness or that suits all interest groups. Also, the magnitude of the potential losses or gains from choosing one policy over another may be less than from the choices available within a single policy.

Model I has the obvious advantage that it requires no government intervention, but it does sacrifice desirable social cost and total loss features available by proper selection of situations of Models II or III.[7] Also, satisfactory operation of Model I when supply is set outside the

[7] Although it can be shown that the free market will minimize social cost under static, equilibrium conditions [10], there is no theoretical proof that this is true when supply or demand is stochastic.

market requires that the target carryover be very close to the amount that those performing the free market stocking function are willing to take at normal or equilibrium prices.

The reserve management policy represented by Model II would be relatively easy to operate. Interested persons could be readily informed about the type and estimated size of inventory adjustments forthcoming. This policy also has the advantage that stocks are somewhat insulated from the market, with the degree of insulation depending on the price spread used. Model II has the disadvantage that an "incorrect" price spread, one set above the equilibrium price, can lead to very undesirable consequences.

Advantages of Model III include low social cost and total loss and the fact that the penalties from choosing an incorrect θ value are not extreme. But this policy could not be used in the form given here with acreage market-determined because of the intolerably high likelihood of zero inventories. The choice of an equilibrium quantity to use as a base for carryover decisions poses difficult problems of estimation.

From an overall point of view, the managed supply conditions provide some advantages compared with leaving the acreage decision to the free market; the former gives generally lower social cost and total loss, more stable conditions and often higher income without great sacrifices in any of the measures reported.

In general, Model II may be preferable to Models I and III. No form of the latter models ranks superior to Model II by all criteria. Model II represents a compromise between the extremes and provides adequate levels and stability of the important variables. Model II also provides a degree of insulation from normal market operations, would be relatively easy to implement and operate, and would be reasonably safe from completely depleted reserve stocks. Combining the overall evaluations given in this study would point to choosing a reserve management policy of the type represented by Model II with the acreage decision made to achieve 400 million bushel carryover and with price limits at least ten cents above and below the equilibrium price.

In brief, the conclusions from the study are as follows:

1. Social cost is relatively small for most storage models considered in this study. For the free market situation I_M, it averages \$17.3 million or 2.6 percent of net farm income from wheat. For the supply and inventory management policy II_4 with price limits of \$1.10 to \$1.30 per bushel for wheat, social cost averaged \$27 million or 4.5 percent of net farm income from wheat.

2. Supply control and inventory management can remove much but not all instability in wheat prices and incomes. The coefficient of

variation of price was 11.7 percent for the free market situation I_M and was 6.8 percent for the autonomously managed acreage coupled with free market inventory (situation I_4). The coefficient of variation of net income from wheat was respectively 26.9 and 21.0 percent for these two models. With both acreage and inventories autonomously managed, the coefficient of variation in price was reduced to as low as 1 percent and in net income to 18 percent.

3. If government involvement in the market occurs on the supply (demand) side, it also tends to be required on the demand (supply) side. Government stock operations work best in conjunction with government (autonomous) acreage determination. And acreage set by the government as in Model I_2, I_4, and I_6 is of dubious worth with stock management solely in commercial hands.

4. Favorable outcomes for Model II, which bases stock operations on price guidelines, depend partly on the ability to estimate an equilibrium wheat price. On the other hand, favorable outcomes for Model III, which bases stock operations on the equilibrium demand quantity, depend on the ability to estimate equilibrium quantity. Model III appears to require more difficult and sensitive judgments. Thus Model II is preferred to Model III. Furthermore, the outcomes of Model II, even with a quite wide price spread, are unlikely to be highly unfavorable because commercial stock adjustments will cushion price and income adjustments within the price boundaries. Hence Model II, with the allowed price spread at least 10 cents above and below the equilibrium or expected market price per bushel may be the most satisfactory storage policy based on the results of this study.

5. Prices and incomes are depressed by a high target carryover under Models I and III but only by a nominal amount under Model II. The most satisfactory inventory Model II does not appear to benefit much from a target carryover above 400 million bushels when acreage is set autonomously. The coefficient of variation is the same for Model II in the case of prices and income whether the target carryover is 400 or 600 million bushels. A target carryover of 200 million bushels does not entail large total loss (storage and social cost), but is rejected because of frequent zero inventory. The recommended policy is to set current wheat allotment so that at expected yields, wheat production will be 400 million bushes plus expected utilization.

6. The models of this study make no provision for minimum working stocks required for normal market operations at the end of the marketing year — just before the new crop comes in. The "pipeline" stocks, 50 — 100 million bushels, could be added to the desired carryover of 400 million bushels and expected utilization.

7. Direct payments could be used in conjunction with the policies considered to supplement farm income. In fact, the benefits of greater price and income stability from government inventory management appear inadequate alone to induce farmers to accept production controls that gear supply to utilization. Thus some form of payment to farmers might be required to implement the stabilization policies reported herein.

8. Guides to handling wheat stocks by geographic area, type and quality, and day to day additions or withdrawals lie outside the scope of this study.

9. The supply and demand quantities of wheat are stochastic variables in this study, but the structural parameters are constant. The basic structure of supply and demand change less for wheat than for many other major farm commodities. But the optimal inventory management policies may change over time and should be updated as structural changes become apparent in the wheat industry.

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