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Reserve Stocks of Grain: A Review of Research

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RESERVE STOCKS OF GRAIN: A REVIEW OF RESEARCH. By Rodney L. Walker and Jerry Sharples. Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 304

ABSTRACT

Research and theory related to reserve stocks accumulation is reviewed. The objectives of holding reserves, storage rules, market conditions, and evaluation of storage rules in achieving objectives are considered. Major conclusions are: There is no one optimal stocks policy; in future models to analyze alternative stocks policies, the demand portion needs to incorporate a more thorough demand-for-U.S.-exports component; future studies should examine substitutability in demand for all food and feed grains and oilseeds; supply, in addition to being considered a function of stochastic yields, should also be defined as a function of planted acres, where acreage responds to market conditions and public farm programs; and public vs. private control needs to be examined.

Key words: Grains; reserves; supply; stability; price; food; stocks; policy.

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TABLE OF CONTENTS

	Page
Summary	iii
Introduction	1
Basic Components of Reserve Stocks Analysis	2
The Objectives	2
Storage Rules	5
Market Conditions	7
Evaluation of Objective Functions	10
Three Empirical Models	10
The Gustafson Model Study: 1958	10
The Gislason Model: 1961	14
The Tweeten Model: 1971	17
Conclusions	19
Objectives and Storage Rules	20
Market Conditions	20
References	22

SUMMARY

Recent interest in reserve stocks can largely be explained by two factors: (a) recent low stocks of grains and oilseeds around the world and (b) changing world conditions which appear to dictate that the U.S. grain market will have volatile prices in the future unless policy measures are used to moderate those conditions. Should the United States have a reserve stocks policy? If so, what kind? Research is needed to help answer these questions. This report reviews previous research and theory related to reserve stocks accumulation in order to give some direction to the current round of research.

The literature reviewed gave valuable insights into model building and theory, but because of rapid structural changes taking place in the U.S. and world markets, most of the results were out of date. Current estimates are needed. New models can incorporate the strengths of the old and include changes in data and model structure consistent with changes in the real world market structure.

This review of research considers each major component of reserve stocks analysis: (a) the overall objectives of holding reserve stocks, (b) the types of storage rules used to achieve the objectives, (c) the market conditions modeled, and (d) evaluation of the storage rules in achieving specific objectives. Major conclusions reached from the review are:

1. There is no one optimal stocks policy. There are many objectives that might be achieved by holding reserve stocks and for each objective there might be an optimal stocks policy. In reality, society will eventually want to achieve multiple objectives, making the search for an optimal stocks policy even more difficult.

2. In future models built to analyze alternative reserve stocks policies, the demand portion will need to incorporate a more thorough demand-for-U.S.-exports component. Shifts over time in the short-run demand function should also be included to allow for growth in demand.

3. Future studies, instead of analyzing one commodity or one group of commodities, should include an examination of the substitutability in demand of all food and feed grains and

oilseeds. When supplies are short, how widely will grains substitute for each other? What are the implications for the size of reserve stocks for each grain?

4. In past studies, supply was primarily a function of stochastic yields. The next round of studies should also define supply as a function of planted acres, where acreage responds to market conditions and public farm programs.

5. A major issue needing evaluation in future stocks models is, "given the various objectives for having reserve stocks, does it make any difference who controls the stocks?" What does economic theory have to say on this issue? Does public control lead to greater social well-being? If there were no public reserve stocks, would the private sector hold a socially desirable level of stocks? Can public control be separated from political manipulation? Some of these questions can be researched and should be addressed in future reserve stocks models.

RESERVE STOCKS OF GRAIN: A REVIEW OF RESEARCH

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INTRODUCTION

U.S. grain stocks began accumulating in the 1950's as a result of price support programs, and during the 1954-62 period, these stocks rose to levels that significantly surpassed annual utilization (table 1). The stocks were drawn upon during the Korean Conflict; during 1966, when world food needs were unusual; and during the early 1970's as a result of corn blight and growing foreign demand. For the 1973 and 1974 crop years, ending stocks were only about 13 percent of utilization for wheat and about 10 percent for feed grains. Soybean stocks are up after the extremely tight situation prior to the harvest of the 1973 crop.

World conditions affecting food have become so volatile that small changes in supply and demand can often cause major market reactions in the United States. Cochrane (2) lists these factors as (a) nearly half of the world being near starvation, (b) demand for grain being highly inelastic, (c) demand for meat abroad being inelastic, and (d) reserve stocks of grain abroad being very small.1/ The United States could dampen the volatile market impact of these factors with reserve stocks.

Because of current low stock levels and tight world food supply conditions, there is renewed interest in establishing new national and international policies on reserve stocks.

Table 1.--Beginning U.S. stocks as a percentage of annual utilization.

Year	Wheat	Rice	Feed grains	Soybeans
1935-53.....	31	5	17	2
1954-62.....	102	32	43	3
1974.....	10	5	12	16

Source: 1935-62 (9), 1974 (18).

1/ Underscored numbers in parentheses refer to literature listed at the end of this report.

This report reviews the literature on research and theory related to U.S. accumulation of reserve stocks of grain and soybeans.[2] Speeches, a review of past stock policies, and management techniques for handling day-to-day problems of purchase and sale of stocks are not covered here.[3]

This review consists of three parts. First, the basic components of stocks analysis are presented. Second, three models are reviewed that contain all the basic components. And third, conclusions are drawn about the present state of reserve stocks analysis, and suggestions are made for future research.

BASIC COMPONENTS OF RESERVE STOCKS ANALYSIS

Any analysis of reserve stocks should implicitly or explicitly include four components: (a) the overall objectives to be achieved by reserve stocks, (b) the types of storage rules that will be used to achieve the objective, (c) specification of market conditions--for instance, supply and demand conditions and the role of government, and (d) a method for evaluating the effectiveness of storage rules in achieving specific objectives. The literature reviewed here contains comments on each of these components.

The Objectives

Waugh (20) observed that society had seven reasons for maintaining a reserve stock of grain:

1. Provide working stocks.
2. Reduce danger of food shortages at home and abroad.
3. Help maintain commercial exports--i.e., a dependable and steady supply.
4. Help stabilize farmers' incomes and the general economy.

---

[2] In this review the term "reserve stocks" refers to working stocks plus any additional stocks held under public or private control at the end of a crop year just prior to harvest.

[3] The reader will find a review of historical policy approaches to stocks management in Bailey, et al (1) and a discussion of alternative grain reserve policies in Steele (15).

5. Along with production adjustment, to raise the level of farm prices and income.
6. Assist growth of less developed countries (LDC's).
7. Foster private industry.

McMinimy and Kutish (9) said that the first and seventh objectives would be achieved by any stocks policy. They ranked the remaining five in order of importance to them: 1-reduce food shortage danger, 2-stabilize income, 3-maintain exports, 4-raise prices, and 5-assist growth in LDC's.

More recently, a task force of the Council for Agricultural Science and Technology put together a list of six "benefits of a conscious reserve stocks policy" (16):

1. Protect producers from unstable markets.
2. Protect consumers from unstable markets.
3. Enhance the commercial export market.
4. Reserve stocks may be a less expensive method of achieving food security
5. Reserve stocks help meet a moral obligation to developing countries.
6. They are an important foreign policy bargaining tool.

Ideally, these objectives are measurable and one can observe in the real world and in the economic model whether progress is being made in achieving the objectives. Four of the more common objectives are reviewed here.

Target Quantities of Stocks

One of the most familiar objectives is to maintain a target level of reserve stocks. Three examples in the research literature are Wells and Fox (21), a National Agricultural Advisory Committee study (14), and Waugh (20). These studies suggested the following target levels of reserve stocks:

	Wells & Fox 1952	NAAC 1964	Waugh 1967
Wheat (mil. bu.)	450-500	630	550-650
Cotton (mil. bales)	4.5-5.0	6.2	5.0-6.0
Feed grains (mil. tons)	1/25-38	45	35-45
Rice (mil. cwt.)	---	9	10-12
Soybeans (mil. bu.)	---	100	---

1/ Corn only.

Source: Waugh (20).

Wells and Fox based their targets on variations in U.S. crop yields during a 50-year period. They sought a stock level that was adequate to offset a year with very low yields followed by a year with moderately low yields. The NAAC study was especially concerned with national security and increased world needs. Waugh's target stocks were based upon variations in yield, acreage, and demand "supplemented by the judgement of several economists" (20, p. 52).

The suggested target levels were meant by the authors to be rule-of-thumb estimates of the magnitude of U.S. stocks needed to provide reasonable market stability and (where cost was analyzed) at reasonable cost. They are relevant to the supply and demand conditions at the time of the studies. They do not, however, address the issue of how to use the target levels once they are defined. As Gustafson points out, this target-level approach "is necessarily an inadequate solution to the storage problem" (4, p. 6). He points out that an administrator of such a program has no way of knowing if at any given point in time he should be adding to or subtracting from stocks, e.g., if stocks are low and there is a poor crop year, should stocks be increased or decreased?

Stocks Target as a Percentage of Trend Production

An alternative to maintaining absolute target quantities of stocks is maintaining a reserve stock level that is a percentage of the trend production level. Bailey and others (1) examine various levels of grains stocks at 4 to 12 percent of the U.S. production trend. Storage costs, net accumulation of stocks, and the relative ability to overcome world shortfalls in production are examined over a historical period. This objective allows for trends in production and utilization over time, but it is still subject to the same criticism as the previous objective.

Reduce Price Variation

Another objective is to reduce price variation over time by putting upper and lower bounds on grain prices. When prices are high, stocks are released; when prices are low, stocks are purchased. Cochrane (2) recently proposed a reserve stocks program that would have the objective of maintaining stable U.S. price levels for grains. He suggested, however, that additional policy tools--such as supply controls when supplies were short--would be needed to help stabilize grain prices. Cochrane warned that it might be politically tempting to use the reserve stocks program not only for stabilizing prices but also for holding farm prices permanently above world levels.

Gustafson anticipated the problem of which Cochrane warned. The major weakness of the price stabilization objective, Gustafson pointed out, was the problem of properly setting the price bounds. Too high a stock level might result over time if the price bounds were too high, or stocks might be depleted too quickly if the bounds were too low. Future price trends would have to be accurately predicted.

Maximize Social Welfare

Waugh (19), Oi (10, 11), and Massel (7) address the issues of price variability over time along given supply or demand functions. Waugh, using relative areas under a demand curve, demonstrates that consumers are not better off with price stability as long as the weighted average price over time (given a static demand schedule) is greater than the stabilized price. Oi uses the same logic to show that producers are not better off with price stability. These two ideas were combined by Massell into one model to evaluate the welfare aspects of price stabilization for both consumers and producers. Massell, using the Waugh and Oi concepts in one equilibrium model containing a static demand curve and a randomly shifting supply curve, demonstrates that there is a net social gain from price stabilization. He then shows graphically and algebraically the gain to be made by storing some quantity during the overproduction year and selling it during the underproduction year.

Samuelson (12, 13), however, points out a basic flaw in the Waugh and Oi interpretation and shows that consumers and producers separately benefit from price stability. He did not mention the Massell article, but Samuelson's argument with the Waugh and Oi papers raises doubt about Massell's interpretation. The disagreements among reputable economists suggest that if the objective of maximizing social welfare (working with consumer and producer surplus) is to be used in a research model, then the conflicts appearing in the literature will have to be resolved.

In his model, Gustafson (4) maximizes the total value of production--the integral of the demand function from 0 to the quantity consumed--over time. On the other hand, Tweeten (17) minimizes the net social cost over time. These models are discussed on pages 10-19.

Storage Rules

A storage rule defines how reserve stocks will be managed in order to achieve a specified objective.[4/] Included in the definition

[4/] This definition is broader than the definition used by Gustafson (4, p. 2). He defined a storage rule as the functional relationship between supply and reserve stocks, whereas the definition used in this report includes not only supply, but other variables as well.

is precisely how much should be added to or taken from reserve stocks in a given year. Heady (5) emphasizes that a reserve stocks program should be "actuarially (statistically) determined" and "subject to a precise set of rules"--that is, a storage rule should be statistically defined and then used. He also pointed out the necessity of the whole system knowing what the rule was and how it operated.

Five of the more common storage rules stated (or implied) in the literature are summarized below. The questions of who enforces the storage rules, the mechanics of how purchases or sales are made, and who does the storing are important but they are not addressed in this report.

1. Reserve stocks = a constant target quantity. This is a naive storage rule and is discussed only for illustrative purposes. Strictly interpreted, no accumulation or use of stocks is allowed once the target is reached. Loosely interpreted, the rule makes little economic sense, because it ignores prices. Thus, stocks would build up to the target during periods of high prices and shortages and would drop down to the target during periods of low prices.

2. Reserve stocks = f(production). Both Waugh (20) and Bailey (1) suggest storage rules where reserve stocks are a function of production. When production is above average or above a trend line, stocks are to be accumulated and when production is below average or below a trend line, stocks are to be depleted. This storage rule is defined by stating the functional form of the equation.

3. Reserve stocks = f(price, loan rate, target stocks). Recently, McGrory (8) defined a storage rule as a function of price, loan rate, and target stocks. His proposal expressed target carryover stocks as a percentage of U.S. domestic, commercial demand levels, plus predictable U.S. concessional sales, plus U.S. food aid. Target carryover stocks in his proposal were: food grains--50 percent, feed grains--25 percent, and oilseeds--25 percent. Target carryover stocks include pipeline stocks. The Secretary of Agriculture could use set-aside provisions in conjunction with the loan rate provisions to regulate carryover. The loan rate for soybeans, however, would need to be set at 2.7 times the corn loan rate.

McGrory's proposal set the following storage rules: (a) if stocks fall to 50 percent of target levels, CCC cannot sell stocks for less than 200 percent of loan rates, and (b) if stocks are over 50 percent of target levels, the CCC can sell at the market price if it exceeds 115 percent of the loan rate plus carrying charges.

4. Reserve stocks = f(price). This rule is generally specified in terms of upper and lower price bounds on the commodity to be stored. If the market price drops below the lower bound, stocks are accumulated and if the price exceeds the upper bound stocks are depleted. Tweeten (17) uses this type of storage rule in his model (see pp. 17-19)

5. Reserve stocks = f(supply). The storage rule used by Gustafson (4) is to make reserve stocks a function of supply--beginning stocks plus production. The relationship can be rewritten as: Ending reserve stocks = f(stocks carried over from previous year plus production). In general, as supply increases, reserve stocks carried over to next year increase. Estimation of alternative forms of this function are discussed in the review of Gustafson's model on pages 10-13.

Market Conditions

Any model used to analyze reserve stocks contains an actual or implied set of market conditions, including production or supply, demand (domestic or foreign), and storage costs. The model may contain other components related to (a) market conditions, such as varying discount rates for expected future costs or returns from storage, (b) which variables should be considered stochastic over time and which should be assumed deterministic, (c) whether it is a free market or whether there is government intervention, and (d) are market conditions static or dynamic over time.

Supply and Demand

The pre-1960 studies generally assumed that demand for individual crops was either static or shifted at a steady and predictable rate. Foreign demand for U.S. grain was a relatively minor consideration. The justification for reserve stocks rested upon the more unpredictable supply function--or more specifically, upon yield. For example, the Wells and Fox (21) target levels of reserve stocks were based upon an analysis of U.S. crop yield variations during a 50-year period. Gustafson (see pp. 10-13) also included yield as the only stochastic variable in his model.

In a study of domestic production since 1927 of major crops, Waugh (20) showed that good years tended to be grouped together and poor crop years tended to be grouped. Reserve stocks would need to be larger under these circumstances than if the same good and poor crop years were randomly distributed over time. Waugh also found that when one crop has a poor year, other crops tend to have poor years as well, reducing the possibility of substitution among crops.

Bailey, et al (1) observed that shortfalls in U.S. crop production occurred less frequently than did above average crops, but that the shortfalls were of greater magnitude than were the increases.

As foreign demand for grains and oilseeds grew, research emphasis shifted to the role of import demand in determining the size of reserve stocks. Both Bailey (1) and Waugh (20) analyzed the possibility of one country's shortage being offset by another's surplus in a given year. Waugh analyzed intercountry correlations in crop production and found that 23 of 26 correlations were positive, indicating that when one country had a short crop, many others were also short. Thus, sometimes shortages in individual countries add up to a global shortage rather than being offset by other countries' surpluses. Analysis reported by Bailey substantiated these conclusions.

McMinimy and Kutish (9) thought there was considerable substitutability among grains in consumption. Thus, the reserve level could be specified as (a) small reserves of each type of grain or (b) bulk of the reserve in the form of "total grain" or a combination of food and feed grain. They pointed out that in Europe, 20 to 30 percent of the wheat was fed to livestock, while in India sorghums were successfully substituted for wheat, and wheat for rice. Thus, a smaller total reserve might suffice than if the objective were to maintain separate reserves for each grain.

After examining trading trends for major wheat importing and exporting countries, Mackie (6) concluded that the major factors affecting world wheat supply and demand were the level of North American stocks (Canada and the United States) and fluctuations of supplies in the central plan countries. He found that 93 percent of the deviation about the trend in wheat imports between 1963 and 1974 was accounted for by the USSR, China, and Eastern Europe. Of the deviation about the trend in wheat exports, 92 percent was accounted for by the United States and Canada. Most other importers and exporters exhibited relatively stable trends.

Discount Rate and Risk

The discount rate is an important variable in the analysis of reserve stocks when future returns from those stocks are evaluated. Assume the objective to be evaluated in a stocks model is to maximize present value of future returns. At what rate should future returns be discounted to the present? As the discount rate goes up, the present value of future returns from reserve stocks declines and consequently the quantity of reserve stocks decreases.

The discount rate also plays a role in determining who holds stocks. Waugh (20) suggests that private industry would store less than desired by society because industry would charge a significantly larger discount rate. Thus, government would need to hold stocks as well, or subsidize private industry to hold additional stocks.

One reason for a higher discount rate by private firms is the risk involved in their holding stocks longer than 1 year. Methods are not now available or customary for hedging against this risk. It has been suggested (16) that private traders could hedge by (a) developing a 2- to 3-year futures contract market or (b) entering into longer term contracts with domestic and foreign buyers.

Storage Cost

Except to point out that at higher storage costs, less reserves will be held, little is mentioned in the stocks literature on storage costs. Most studies use a fixed storage cost per unit stored. For example, Bailey (1, p. 9) used $5 per ton or about 15 cents per bushel for 1 year's storage to estimate storage costs at various levels of reserve stocks.

Costs of reserve stocks storage were discussed by the Council for Agricultural Science and Technology (14). Their main points were:

1. Storage costs are generally lower in the United States than in importing countries.
2. Cost analysis should account for any price-depressing effect of reserves on the market.
3. Cost analysis should also show the reduction in land diversion costs foregone.
4. Recent examples of average storage costs:

		10% interest	UGSA rate*	Total
Wheat	- market 4.50	.45	.15	.60
	- target 2.05	.21	.15	.36
	- loan 1.37	.14	.15	.29
Corn	- market 2.50	.25	.15	.40
	- target 1.38	.14	.15	.29
	- loan 1.10	.11	.15	.26

*Uniform Grain Storage Agreement

Evaluation of Objective Functions

The evaluation of the objective function and resulting storage rule furnishes policymakers and other interested parties with information concerning how the objective and storage rule(s), if adopted, will affect the economy. The researcher should provide some criteria for evaluation of both benefits and costs of the program analyzed if his research is to be useful to policymakers. This topic is discussed more fully in the following sections.

THREE EMPIRICAL MODELS

Supply and demand have changed considerably since the 1952 Wells and Fox study (21), in which yield was the only major stochastic variable analyzed. The later Waugh analysis (20) included variances in yield, acreage, and foreign demand, but the linkage among these variables and the suggested target levels were primarily subjective. The three studies reviewed below each provide a formal model linking supply and demand and storage rules. They also provide a framework based upon economic theory that can be used to compare alternative storage rules. The discussion focuses on how each author treated the four basic components of stock analysis as previously outlined.

The Gustafson Model Study: 1958

Objective

Gustafson (4) chose to derive a storage rule that would maximize the sum of discounted expected net gains to society from consuming grain over time. Because of variable production over time, storage between production periods would be needed. He defined net gain in any year resulting from storage as the total social value of grain

utilized under the storage program minus the cost of storage. Gustafson used the area under the demand curve for the commodity under consideration as the measure of total social gain in one time period. The methodology used to define the rule is discussed after the remaining components of the model are presented.

Market Conditions

Gustafson utilized a linear demand relation where price equals a constant, minus a slope coefficient, multiplied by the quantity of grain utilized. The price level of all other goods was assumed constant and this demand function was assumed to be fixed over time. Furthermore, the demand for feed grains was assumed to be completely domestic demand (export demand was assumed to be zero).

Supply of feed grains was assumed to be a functional relationship between acreage planted, which was a constant, and yield, which was assumed to be a random variable with a known distribution. The assumption of constant planted acres was not too unrealistic during the 1950's. The role of government in Gustafson's analysis was restricted to that of determining the level of carryout for feed grains.

Storage Rule

Gustafson defined the storage rule as the unique function Θ which satisfies the following equation:

$$V = \left(\frac{1}{1+r}\right) \int_0^{\infty} P[C + X - \Theta(C + X)]\, f(X)dX - \gamma^1(C)$$

where V = total expected social value over time discounted to the present,

$\frac{1}{1+r}$ = the discount rate,

r = the interest rate,

P = the demand function for feed grains,

C = the carryover of feed grains from the previous period,

X = total production

$f(X)$ = the probability distribution function of production,

γ^1 = the marginal cost of storage.

The storage function Θ then is simply a function of total available supply. The function Θ is found by employing dynamic programming, since the above equation must be satisfied by the storage function Θ for all years in the planning horizon. Figure 1 presents one such derived from the following assumptions.

Optimal Carryover Bushels Per Acre for Feed Grains

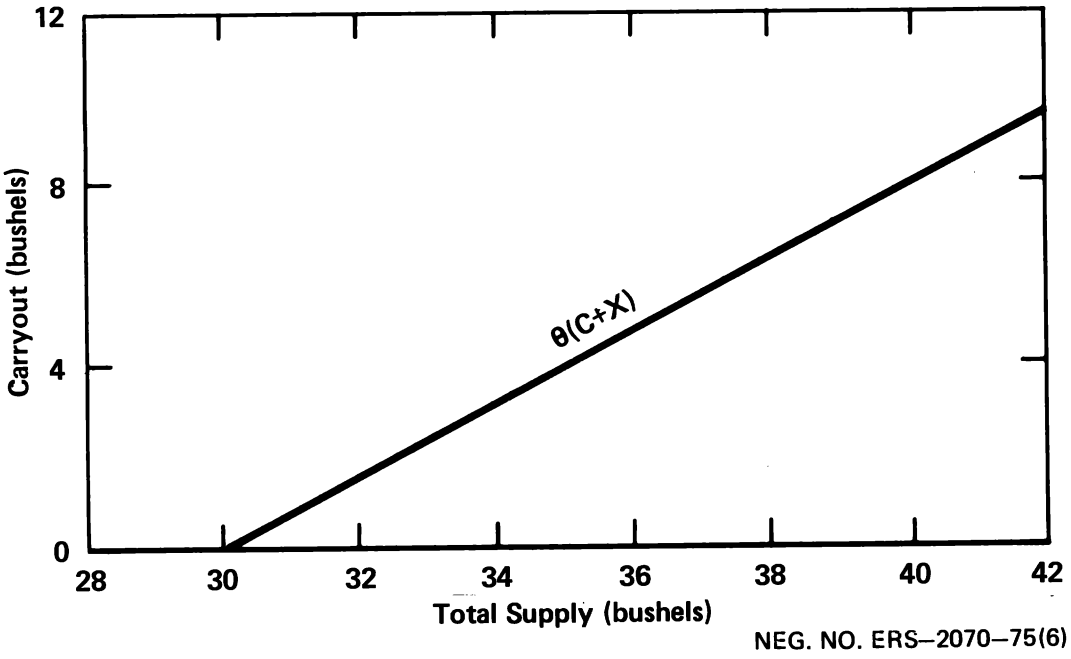

Figure 1.

Since a constant acres planted was assumed, aggregate demand and supply were reduced to demand and supply on a per acre basis.

Demand: $P = \$6.50 - \$0.167(Y)$ Y = bushels per acre
Supply: μ = 30 bushels per acre σ = 3 bushels per acre
Cost of Storage: \$0.10 per bushel
Interest Rate: 5%

Figure 1 shows the relationship between total supply (horizontal axis) and carryout (vertical axis). The diagonal line is a graph of the optimal storage rule Θ. If total supply fell below the equivalent of a 30-bushel-per-acre yield (the expected yield), no stocks would be carried over to the next year. If supply were equivalent to yields above 30 bushels, the carryout stock would increase as shown. Remember, this study used pre-1950 data.

In deriving his storage rules, Gustafson assumed a constant marginal cost of storage. Although the selection of the discount rate was somewhat arbitrary, prevailing rates were used.

Evaluation of Objective Function

Gustafson derived storage rules for only one objective function. Therefore, evaluation or comparison of alternative objectives could not be provided. Gustafson did, however, perform a sensitivity analysis on his results. Table 2 summarizes this sensitivity analysis and illustrates the effect of changes in the elasticity of demand, storage cost, and yield variability on optimal carryover for feed grains (corn, oats, and barley in corn equivalent) with an assumed 140 million acres planted to feed grains. Table 2 indicates that optimal carryover is sensitive to changes in demand elasticity, yield variability (supply), the cost of storage, and the discount rate.

Table 2.--Alternative carryover levels for feed grains

	Unit	1	2	3	4	5
Elasticity of demand		0.5	0.5	0.3	0.5	0.5
Cost of storage	Dol./bu.	.10	.04	.04	.04	.10
Discount rate		.02	.02	.02	.02	.05
Yield variability	Bu./acre	3.03	3.03	3.03	5.05	3.03
Optimal carryover	Mil. bu.	270	396	578	620	242

Gustafson illustrated mathematically how his basic model could be modified to include the effects of foreign demand and supply. Gustafson shows that although he specifies the model to maximize gain to the general public, the method of solution can be modified to maximize gain to farmers or any other sector. He also points out that the model is specified "... in terms of net gains or losses arising from changes in quantities stored or utilized rather than in terms of price stabilization", but "the carryover rules ... can easily be converted to equivalent price-setting rules."

The assumptions of static demand and a constant acreage planted to feed grains restrict the usefulness of his model, but all other basic economic variables related to carryover are included. He also points out two major implications from his results. The first is that the quantity of grain stored by private firms maximizing expected net revenues in a competitive market would be the same as the quantity of grain stored by a government agency maximizing the sum of discounted expected social gains. The second implication is that if the government operates the storage program directly, given Gustafson's assumptions, the expected cost to the government of operating an optimal program is zero.

The Gislason Model: 1961

Objectives

Gislason (3) derived storage rules for two alternative objectives. The first objective was to derive a storage rule for the private sector with profit maximization as the objective. The second objective was to derive a storage rule for the public sector with profit maximization of net returns from an ever-normal granery model as the criterion for optimization.

Storage Rule for the Private Sector

The storage rule for the private sector model results from assuming that firms in the private sector compare the price they expect to receive for the commodity in the next period with the price in the current period. If the difference between the two prices is greater than the cost of storage, then storage is undertaken. If the difference is less than the cost of storage, then no grain is stored. The quantity stored is determined as follows:

Net returns from storage can be written as

$$(1) \quad P_1 - P_0 = C$$

where P_1 = price next year,

P_0 = current year,

C = cost of storage.

Gislason assumed a perfectly competitive market with aggregate profits summing to zero. Thus, equation (1) results. He further assumed a linear demand function of the form:

$$P = a - bQ$$

Therefore, by subtracting the quantity to be stored (S) from current supply (X_0) the demand function for the current year becomes:

$$(2) \quad P_0 = a - b(X_0 - S)$$

Let $\hat{H}$ be the expected harvest next year. Assuming all grain available next year is consumed, the demand for the next year becomes:

$$(3) \quad P_1 = a - b(\hat{H} + S)$$

Now, substituting equations (2) and (3) into (1) and solving for S:

$$S = 1/2[X_0 - \hat{H} - \frac{C}{b}]$$

Where the quantity to be stored is a function of total available supply (X_0), expected harvest next year ($\hat{H}$), the cost of storage (C), and the slope of the demand curve (b).

Market Conditions

In the private sector model, Gislason assumed a perfectly competitive market with a further restrictive assumption that aggregate profits for the industry as a whole sum to zero. This assumption of zero aggregate profits allowed him to ignore the effect of discounting. Therefore, the Gustafson model, discussed previously with a discount rate of zero, is approximately equivalent to Gislason's private sector storage model. Gislason employed a linear demand function which was assumed to be stationary over time with the price levels of all other goods held constant. Gislason also assumed an isolated economy (no foreign demand).

Supply was assumed to be a constant, known with certainty by the private sector.

Evaluation of Results

Gislason derived a theoretical storage model for corn using an assumed price elasticity of demand of -.65 for the period 1926-40, total yearly production of 2,367 million bushels, an average price of 72 cents per bushel, and a constant storage cost of 10 cents per bushel. He then applied his rule to production during 1926-37. Table 3 compares actual carryover with the optimum carryout obtained by using the private sector storage rule. Gislason did not perform a sensitivity analysis, although he did compare the carryout obtained by employing his private sector model with actual carryout of corn. These comparisons are shown in table 3.

Storage Rule for the Ever-Normal Grainery Model

Gislason used the storage function given in equation (1) to equate the marginal cost of storage with the marginal returns to storage.

(1) $S = g(X - Q)$

Table 3.--Actual carryover for corn, compared with optimal carryover for the private and public sectors.

Year	Adjusted actual carryover	Model Results: Private sector model	Model Results: Public sector model
	Million bushels		
1926	128	89	190
1927	21	93	196
1928	62	56	137
1929	63	11	68
1930	114	0	0
1931	179	48	126
1932	283	278	484
1933	273	70	159
1934	16	0	0
1935	106	0	0
1936	34	0	0
1937	262	36	106

where S = quantity to be stored,
X = total quantity of grain available,
g = proportion of the total quantity of available grain in excess of Q (a constant) that is held as carryover stocks.

Gislason shows that marginal cost is equated with marginal returns when:

(2) $b \sqrt{V_0} \ \Delta V_C = C \ \Delta ES$

where b = the slope of the demand curve,
V_0 = variance of crop sizes,
ΔV_C = the change in the variance of consumption with respect to a change in either g or Q,
C = cost of storing a bushel of grain for 1 year,
ΔES = the change in the average quantity stored when either g or Q changes.

Market Conditions

Gislason assumed a static linear demand function solely determined in the domestic market. Supply was assumed to be a random variable and yields were assumed to be normally distributed multiplied by a constant planted acres. The only government intervention was that attributable to operation of the storage rule. The marginal cost of storage was assumed to be a constant.

Monte Carlo Evaluation of Results

The operation of the rule was simulated several hundred times for various values of the parameters g and Q of the storage rule. The storage rule derived for corn for the period 1926-37 is given in equation (3).

(3) $S = .78(X - 2{,}582{,}000{,}000)$

A comparison of actual carryout of corn with that obtained by employing the storage rule is presented in table 3. The Gislason analysis agrees with that of Waugh in that the private sector will store less grain than the public sector. However, when he expanded his models to include world demand he found that the private sector would store more grain than would the public. This result was probably due to the non-stochastic nature of his assumed foreign demand function. The static linear demand and constant planted acreage assumptions do abstract the models significantly. The results are consistent with Waugh's argument that the private sector will store less than the public sector under similar conditions.

The Tweeten Model: 1971

Tweeten (17) used an aggregate U.S. wheat simulation model to evaluate the effects of three alternative storage rules on the mean and variance of twelve variables including (a) prices, (b) receipts, (c) net farm income from wheat, (d) production, (e) stocks, and (f) net social cost (defined as the absolute difference between the area under the demand curve and the area under the supply curve bounded by the given quantity utilized and the equilibrium quantity). The model was designed to apply to the 1970 structure of the wheat industry with an equilibrium starting point of 1.6 billion bushels supply-demand, 62 million acres planted, a 25-bushel yield, and a farm price of $1.20 per bushel.

Market Conditions

Demand consisted of two components: domestic (a function of price) and export (a function of price, quantity exported last year, and a random disturbance). The disturbance term was uniformly distributed between +200 and -200 million bushels.

Production was the product of acreage and yield. Yield was a random variable with the distribution empirically estimated. Acreage was either determined by the market or determined by policy decision.

market determined acreage = .155 (last year's price)
+..7 (last year's acreage)

policy determined acreage = (demand plus desired stocks change)
÷ (yield)

Model I: Model I contained no explicit storage rule. It approximated a free market situation. Demand for stocks was defined as a component of total demand and had the following form:

$$QS_t = 70 \qquad P > 200$$

$$QS_t = 895 - 4.125P_t \qquad P \leq 200$$

where QS_t = carryout stocks (million bushel),
P = price (cents).

Supply was either market determined or determined by policy decision using three alternative levels of carryout: 200, 400, or 600 million bushels.

Model II: A storage rule was defined where stocks were used to achieve domestic price stability and meet emergency needs. Upper and lower bounds on price were set, and stocks were decreased if the market price rose above the upper bound and increased if the price fell below the lower bound.

Model III: The storage rule used in Model III closely resembled that defined by Gustafson. However, instead of using maximized net social gain as the objective, as did Gustafson, Tweeten minimized net social loss. Dynamic programming was used to obtain the storage rule, which was then used in the simulator. The storage rule was:

$$QS_t = \Theta(S_t - 1{,}550)$$

where QS_t = carryout stocks (million bushel),
S_t = supply (million bushel).

The optimum value for Θ was .85, but values from .70 and 1.0 were also used in Model III.

Results

Tweeten did not provide any historical comparisons of his model results with actual carryover. However, his results seem reasonable

given his assumptions and time period. Carryout varied (depending on parameter assumptions and model chosen) from a low of 116 million bushels to a high of over 700 million bushels, and wheat market prices ranged from $0.77 to $1.90 per bushel.

The major conclusion shown by Tweeten is that there is no best or optimal policy for reserve stocks. The optimal policy depends upon the objective(s) being sought. Thus, the mean, variance, and range of several variables are shown in the research report for each solution. Other conclusions are:

1. Social cost is relatively small for most storage models studied.

2. Government stock management operations work best when accompanied with government acreage controls.

3. The success of Model II (using upper and lower bounds on price to determine stocks purchase or sale) depends upon the ability to accurately estimate equilibrium price, while Model III needs accurate equilibrium quantity estimates to provide a successful storage rule. The authors conclude that given their subjective evaluation, storage rules based on Model II are superior to those from Model III.

4. In general, a target carryover of about 400 million bushels of wheat was recommended plus pipeline stocks of an additional 50-100 million bushels.

CONCLUSIONS

Major structural change has taken place since reserve stock levels were estimated by Wells and Fox, Waugh, and others. The empirical studies of Gustafson, Gislason, and Tweeten give valuable insights into model building, but their results are also out of date because of the rapid structural change taking place in recent years. Up-to-date estimates are needed for policy analysis, so additional research is needed. New models can incorporate the strengths of the old and include changes relevant to the changing structure of markets and institutions.

Following is a short critique of how the reviewed literature treated the four major components of grain stocks analysis, as presented in the preceding sections. Suggestions are made about certain aspects of these components which should be expanded in future research on grain stocks.

Objectives and Storage Rules

Three general conclusions can be drawn from the literature about objectives and storage rules. First, there is no one optimal stocks policy. Many objectives are listed in the literature. Each may require unique storage rules, and each storage rule may result in a different level of reserve stocks, given the same set of economic conditions. The three empirical studies reviewed in this report derived storage rules for six objectives. Those objectives were:

1. Maximize expected net social gain (Gustafson),
2. Reduce price variability (Tweeten),
3. Minimize expected net social loss (Tweeten),
4. Maintain storage at alternative specified target carryout levels (Tweeten),
5. Maximize profit from storing grain for one time period only for the private sector (Gislason), and
6. Maximize expected returns to storage for the public sector (Gislason).

Each objective gave different results. Therefore, future research should measure the impact of alternative storage rules on a variety of variables such as the level and dispersion of farm income, prices, stock levels, costs, etc. This comparison is a valuable contribution of Tweeten's study.

Third, storage rules which are concerned with objectives which maximize social welfare need to be reviewed more thoroughly. The question of how to measure social welfare has not been fully answered in the literature. Therefore, an indepth review of this question needs to be performed before analyzing storage rules which use social welfare as a criterion.

Market Conditions

Demand

In the studies reviewed, import demand was incorporated either indirectly or not at all. Foreign demand has become an increasingly important component of aggregate demand for U.S. agricultural commodities. The extreme volatility of this demand, as well as changing exchange rates, have become the rule rather than the exception; thus, both variables need to be included in future studies of grain reserves.

Also in the studies reviewed, the short-run demand functions were static over time. Recent experience suggests that the dynamic nature of demand should be considered in order to evaluate the stability over time of alternative grain reserve proposals.

Finally, the researchers analyzed grain reserve policies for one commodity or one group of commodities, whereas McMinimy (9) and others suggested that there was substantial substitutability in demand for the various food and feed grains. Simultaneous analysis of both food and feed grains would seem appropriate in the future.

Supply

An important question in future analysis is, "what combination of land diversion and stocks management would be optimal for certain objectives?" Tweeten's model contains government acreage management and his results show the two policy instruments can be used effectively together.

All studies treated yield as a random variable, but only Tweeten treated supply as a function of the commodity's own price. An attempt should be made in future analyses to deal with variations in acreage planted.

Private vs. Public Control

A major issue needing evaluation in future stocks models is, "given the various objectives for having reserve stocks, does it make any difference who controls the stocks?" What does economic theory have to say on this issue? Does public control lead to greater social well-being? If there were no public reserve stocks, would the private sector hold a socially desirable level of stocks? Can public control be separated from political manipulation? Some of these questions are able to be researched and should be addressed in future reserve stocks models.

Evaluation of Results

The evaluation of the effects of storage rules on key economic indicators is one of the more important aspects of any research on grain reserve programs. Some indicators that need to be reported are (1) the cost of the program to the government, (2) the mean and variances of prices, income, and production, and (3) exports. Without this information, policymakers and economists cannot effectively evaluate two or more alternative programs. Once a program has been adopted, these indicators are needed so that administrators can measure the progress toward achievement of the program objectives.

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