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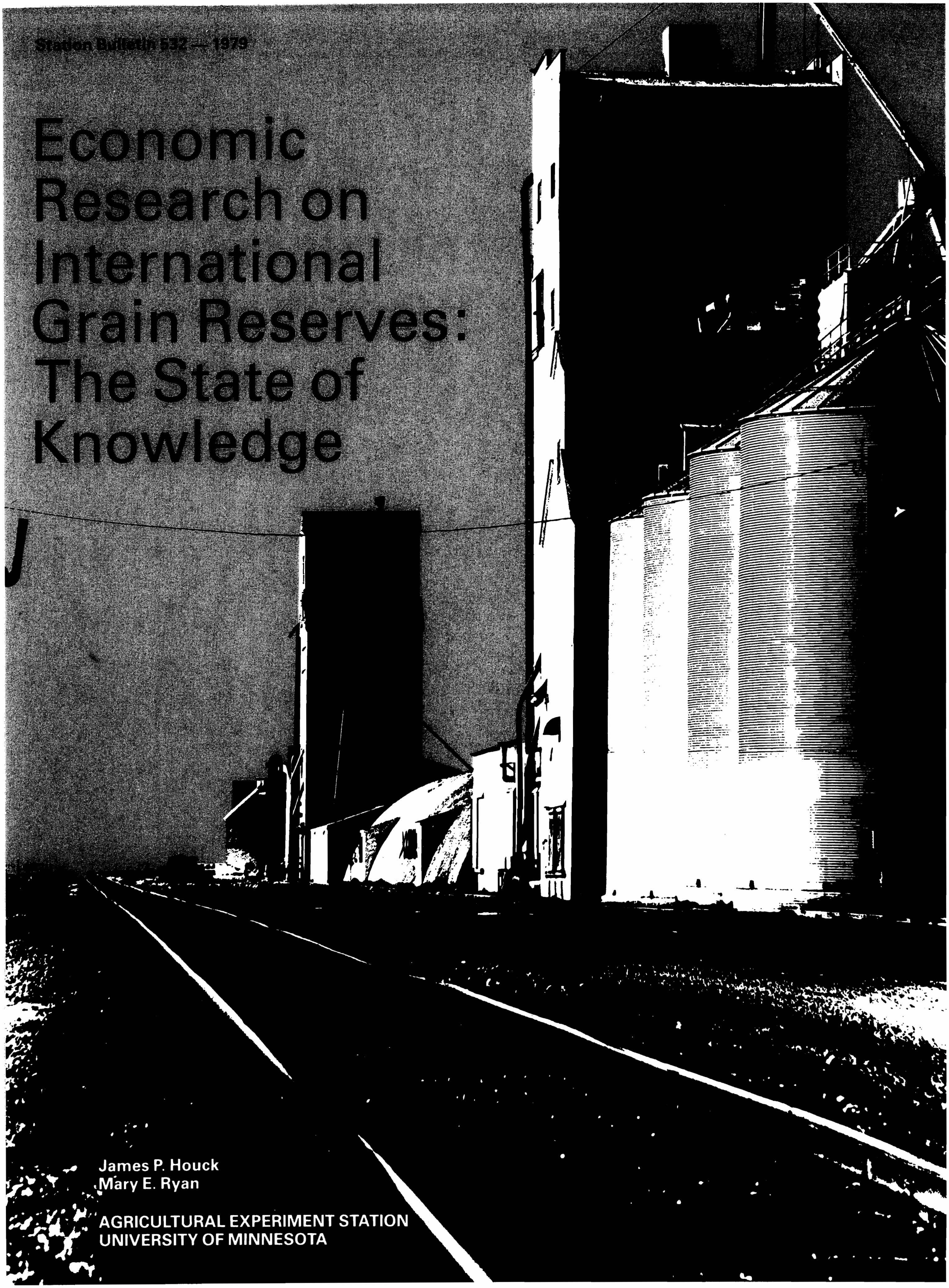
Economic Research on International Grain Reserves: The State of Knowledge



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Foreword

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1. Introduction and Scope

The convulsions that occurred in agricultural markets in the early 1970s profoundly affected the way that governments, international agencies, private firms, and individuals viewed market instability and food security. Governments and multinational bodies began to look seriously at proposals for buffer stocks, commodity reserves, compensatory exchange financing, and other stabilizing schemes. Economic research on these topics mushroomed.

Some of this research was sponsored directly by institutions with an immediate interest in stabilization policy like the Food and Agricultural Organization of the United Nations (FAO) and the U.S. government. Some research was simply a response by many professional economists to an obviously urgent set of circumstances about which previous work was clearly inadequate.

One of the central topics in this work is the economics of deliberate price and market stabilization in agricultural and raw materials markets — both national and international. The stability or lack of it in agricultural markets is not a new problem for policymakers or researchers. But the vigor and diversity of efforts by economists over the past six or seven years to unravel the theoretical and empirical puzzles of commodity market instability are unparalleled. Theoretical work has been undertaken to broaden and deepen our general understanding of how and why deliberate market stabilization can change and rearrange economic well-being among producers and consumers, exporters and importers, buyers and sellers, and others. The empirical work has applied tools of economic analysis and measurement to the study of stabilization in actual markets ranging from wheat to orange juice.

The focus of this report is on empirical research into the size and operation of possible international food and feed grain reserves. Over the years, more technical work has been done on grain reserves than on any other commodity or product group. The reasons are fairly obvious — grain is the basis of mankind's food supply, serious disruptions in world grain supplies have lain at the heart of all the planet's past food crises, and nations have tried for years to reach agreement on some workable grain reserves scheme.

The objective in these pages is to describe, summarize, and synthesize the major published economic research on grain reserves which is international in scope. Results and basic approaches to the problem are emphasized. Methodological details and technical fine points are not probed. Much of the research discussed in this report is scattered throughout the professional literature of economics and is highly technical in its presentation. Our purpose is to bring the major approaches and findings together in a non-technical way, accessible to decision-makers and other interested persons who may not be trained in economics.

Section 2 of this report examines briefly some important data and economic interrelationships in the world grain sector. It provides a perspective of the relative magnitudes against which the empirical research results can be compared. Section 3 is a general discussion of international grain reserves as a topic in applied economic research, including an overview of the objectives, methods, and scope of the studies examined. Sections 4 through 6 contain summaries of the individual grain reserve studies selected for analysis. Section 7 is a summary of the state of knowledge about this topic from the economic research viewpoint.

An important part of this report is the bibliography of many of the materials examined in its preparation (Section 8). This bibliography appears in two parts. The first is a listing of empirical research documents referred to throughout this report. They are listed chronologically by institutional affiliation of researchers, reflecting the classification scheme employed in the organization of Sections 4, 5, and 6. The chronological organization highlights the tendency of these studies to build upon earlier work within the same general category. The references to the bibliography as they occur in the text are by numbers.

The second part of the bibliography is a selected list of articles, monographs, and papers which are reviews, policy and position papers, and educational materials on grain reserves. This second list is briefly annotated, since these items are not discussed in the body of the report. Items included are representative of the main lines of thought about national and international policy in this area. Many draw upon research presented in this paper. The authors cite research they consider relevant to develop strong positions and viewpoints about grain reserves as an international policy tool. They review and comment upon selected empirical studies. In general, these articles reflect the values and judgments of the authors.

The theoretical literature dealing with economic stability and commodity stabilization is wide, deep, and rapidly growing. This work has been surveyed by others recently. A report by Burnstein and book chapters by Turnovsky, Sarris and Taylor, Smith, and Burmeister provide useful overviews and summaries of this literature.[1] It is clear, however, that to date no general, unambiguous, theoretical case can be made either for or against deliberate market stabilization for a nation or the world. Hence, the recent explosion in the empirical analysis of grain reserves is heavily policy-oriented and eclectic. Much of the effort is designed to analyze historical fluctuations, examine the size and cost implications of particular reserve stock proposals, or design reserve stock schemes to meet specific criteria.

[1] Harlan Burnstein, *Welfare Implications of Instability in Agricultural Commodity Markets,* A.E.R.S. No. 132, Department of Agricultural Economics and Rural Sociology, Pennsylvania State University, October, 1977; Stephen Turnovsky, "The Distribution of Welfare Gains from Price Stabilization: A Survey of Some Theoretical Issues," in *Stabilizing World Commodity Markets,* ed. by F.G. Adams and S.A. Klein (Lexington, Mass.: Lexington Books, 1978), pp. 119-148; A.H. Sarris and L. Taylor, "Buffer Stock Analysis for Agricultural Products: Theoretical Murk or Empirical Resolution?" *ibid.,* pp. 149-160; G.W. Smith, "Commodity Instability and Market Failure: A Survey of Issues," *ibid.,* pp. 161-188; and Edwin Burmeister, "Is Price Stabilization Theoretically Desirable?" *ibid.,* pp. 189-191.

2. A Brief Perspective on the World Grain Sector

As various grain reserve research studies are discussed, stockpile sizes, production shortfalls, and similar quantitative figures are presented and compared. Similarly, price levels and degrees of price fluctuation also are examined. To provide a framework for this discussion some general data on the world grain sector are presented here. More detailed information is available in many USDA and FAO publications.

Table 1 shows the total amount of all food and feed grains produced and traded in the world in 1976-78. Notice that only about 12 percent of world production enters into international trade — less than is carried over from one year to the next as stocks. Rice, wheat, and coarse grains, such as corn (maize), barley, oats, and grain sorghum, constitute these totals. While these grains are interchangeable to some extent, substitution is not perfect. Data for individual grains are presented in Tables 2, 3, and 4. The role of major countries or regions in production and trade also is shown.

Rice, shown in Table 2, is now about 18 percent of the world's total grain supply. Because 96 percent of all rice is consumed in the country which produces it, rice amounts to only about 6 percent of total grains which are traded internationally. This, plus the special characteristics of rice production and consumption in Asia, typically results in rice either: (1) being excluded from grain reserves proposals; (2) assuming a minor role within schemes which emphasize wheat and/or coarse grains; or (3) standing alone in specific reserve or buffer stock program proposals.

Wheat and wheat flour (Table 3), represent 30 percent of the current total world grain output and amount to almost half of the world's grain trade. As the world's premier *food* grain in both production and trade, wheat is the centerpiece of most grain reserve proposals and analyses. In addition, about 17 percent of each year's total wheat production is traded across in-

Table 1. World grain data for wheat, coarse grains, and milled rice, average of 1976/77 and 1977/78 (July-June).

Item	Average 1976/77 and 1977/78
	(million metric tons)
World production	1338
Exports/imports	155
Ending stocks	189

Source: Computed from data published by Foreign Agricultural Service, USDA.

Table 2. World rice data, average of 1976/77 and 1977/78 data (milled basis).

Country	Average 1976/77 and 1977/78	
	(million metric tons)	
World Production		241.3
PRC	85.0	
India	48.3	
Indonesia	15.6	
Thailand	10.4	
Others	82.0	
World exports[a]		9.6
US	2.3	
Thailand	2.2	
Others	5.1	
World imports[a]		9.6
Indonesia	2.0	
West Europe	0.9	
Others	6.7	
World stocks (ending)		12.9

[a]Estimated from calendar year data.
Source: Foreign Agricultural Service, USDA.

ternational borders, a higher proportion than either rice or coarse grains. Moreover, stock levels in wheat typically exceed those of rice or coarse grains in absolute value and as a percent of total supplies.

The production and trade data for coarse grains are shown in Table 4. Although the bulk of the world's coarse grains are produced for and consumed by livestock, a significant and changeable proportion is used as human food, especially in Africa and Latin America. The exact split between human and non-human consumption in any one year depends mainly upon relative prices and supplies of these coarse grains, *vis a vis* wheat, and livestock. On the other hand, a relatively small, but changeable, portion of the wheat supply is fed to livestock. Consequently, this potential shifting and switching of roles in utilization means that both wheat and coarse grains are often viewed together in grain reserves discussions (Table 5). This view is strengthened since wheat and coarse grains, together with rice, form the foundation of mankind's food supply whether consumed directly as grain or indirectly as livestock products. The dominance of a few countries and regions in world wheat and coarse grain sectors suggests that they will exert influence on any proposal affecting grain markets.

Underlying the study and analyses of reserve stock programs are the trends in grain output and their year-to-year fluctuations. Figures 1, 2, 3, and 4 illustrate both the trend and year-to-year variation in the world output of total grains, milled rice, wheat, and coarse grains over the 1960-78 period. Each figure also contains a numerical statement indicating the extent of production variability around the estimated trend. (Statisticians call this plus/minus figure the standard error of estimate around the trend.) Comparisons among these figures provide a general idea of the relative instability in total and individual grain production. While actual variations are greatest for coarse grains, the variations in wheat production are largest as percentages of production. A 16-million-metric-ton shortfall is 3.8 percent of 1978 wheat production, whereas an 18-million-metric-ton shortfall is 2.5 percent of 1978 coarse grain production.

Table 3. World wheat and wheat flour data, average of 1976/77 and 1977/78 (July-June).

Country	Average 1976/77 and 1977/78	
	(million metric tons)	
World Production		398.3
US	56.7	
Canada	21.7	
West Europe	49.2	
USSR	94.5	
India	30.0	
Others	146.2	
World Exports		68.1
US	28.5	
Canada	14.5	
Australia	9.8	
Argentina	4.1	
West Europe	7.1	
Others	4.1	
World Imports		68.1
West Europe	6.6	
Japan	5.7	
East Europe	5.6	
USSR	5.8	
PRC	5.8	
Others	38.6	
World stocks (ending)		89.6
US	31.2	
Others	58.4	

Source: Foreign Agricultural Service, USDA.

Table 4. World coarse grain data, average of 1976/77 and 1977/78 (July-June).

Country	Average 1976/77 and 1977/78	
	(million metric tons)	
World production[a]		684.8
US	198.1	
West Europe	80.2	
USSR	103.8	
Brazil	17.1	
Others	285.6	
World exports		82.6
US	51.2	
Argentina	10.0	
Canada	4.2	
Others	17.2	
World imports		82.6
West Europe	31.0	
Japan	16.4	
East Europe	8.4	
Others	26.8	
World stocks (ending)		79.3
US	35.1	
Others	44.2	

[a]Coarse grains are corn, barley, oats, sorghum, rye, and mixed grains.
Source: Foreign Agricultural Service, USDA.

Table 5. World total wheat and coarse grains data, average of 1976/77 and 1977/78 (July-June).

Country	Average 1976/77 and 1977/78	
	(million metric tons)	
World Production		1096.2
US	254.8	
West Europe	198.3	
USSR	93.9	
PRC	111.1	
Others	438.1	
World Exports		150.6
US	79.6	
Others	71.0	
World Imports		150.6
West Europe	37.6	
Japan	22.0	
USSR	14.4	
East Europe	14.1	
Others	62.5	
World stocks (ending)		169.0
US	66.2	
Others	102.8	

Source: Foreign Agricultural Service, USDA.

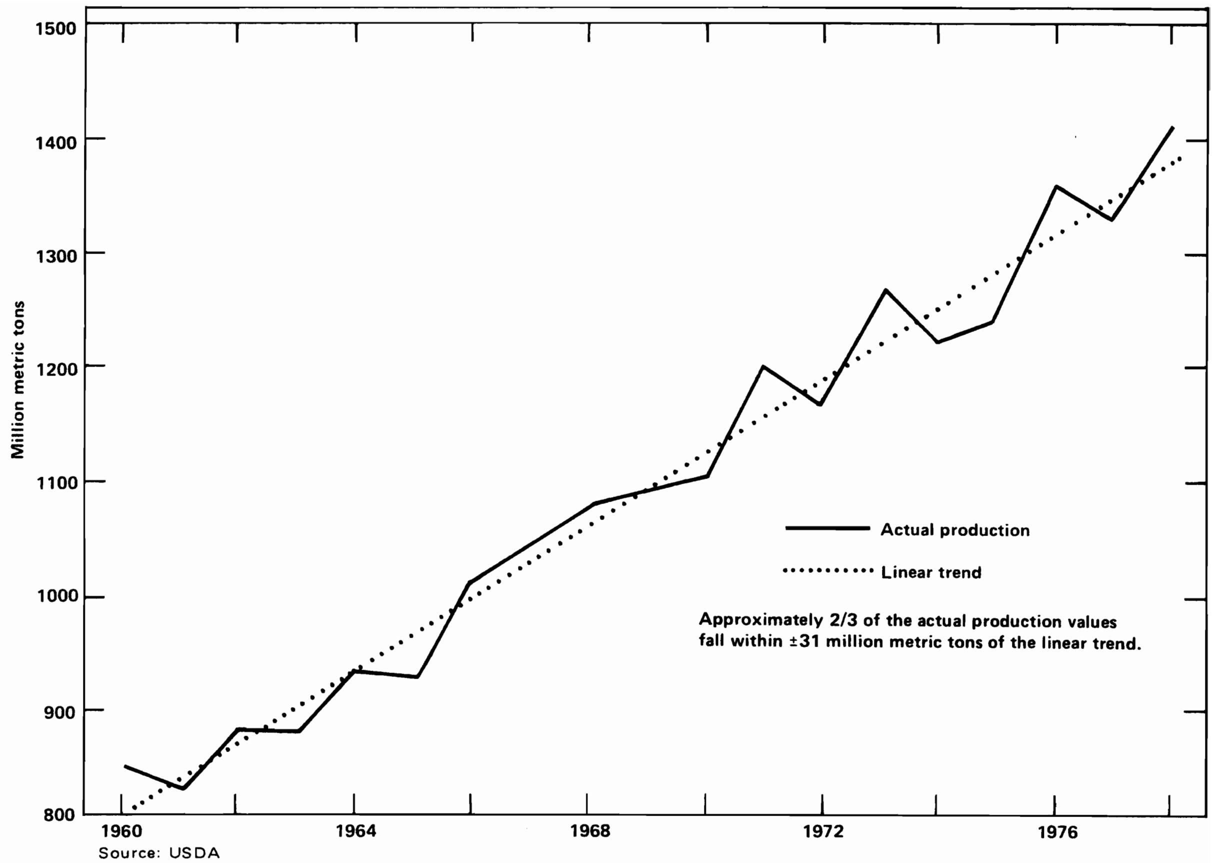

Figure 1. World total grain production.

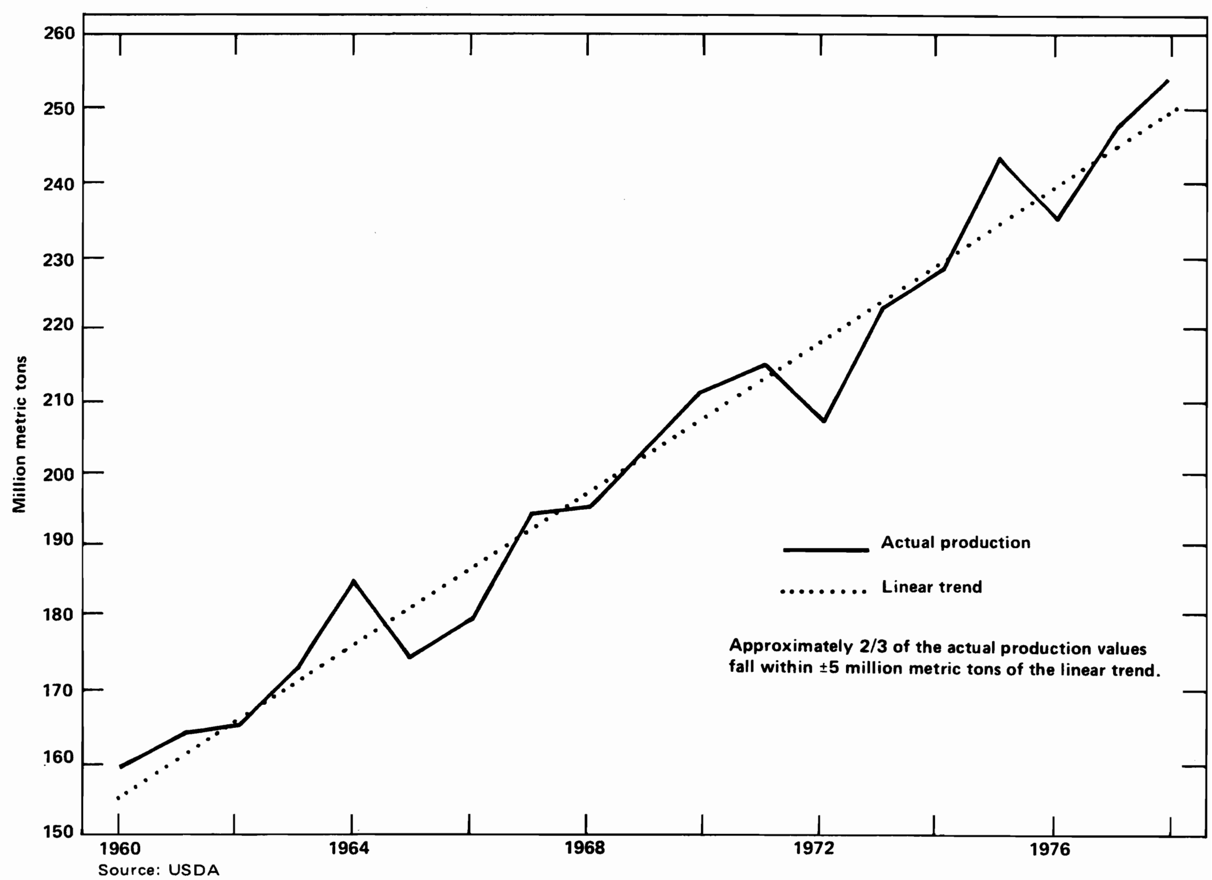

Figure 2. World milled rice production.

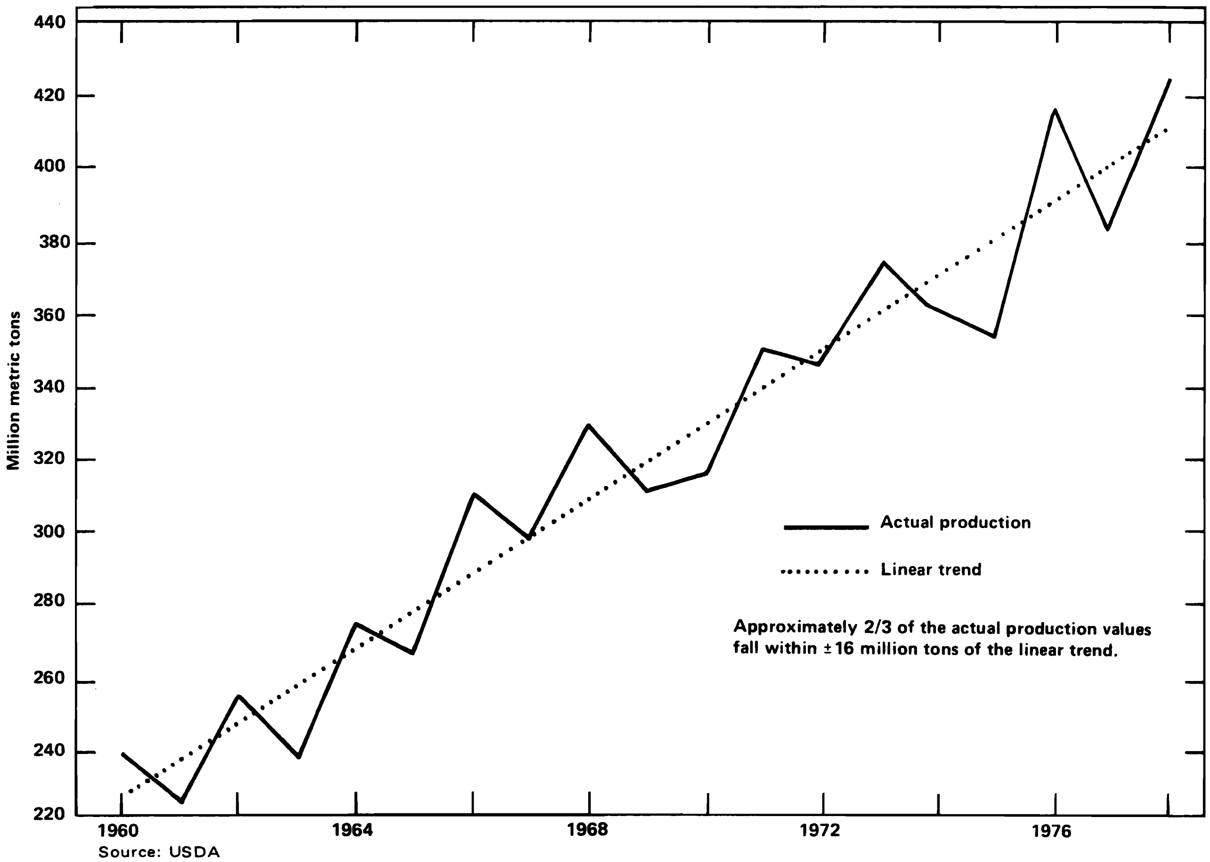

Figure 3. World wheat production.

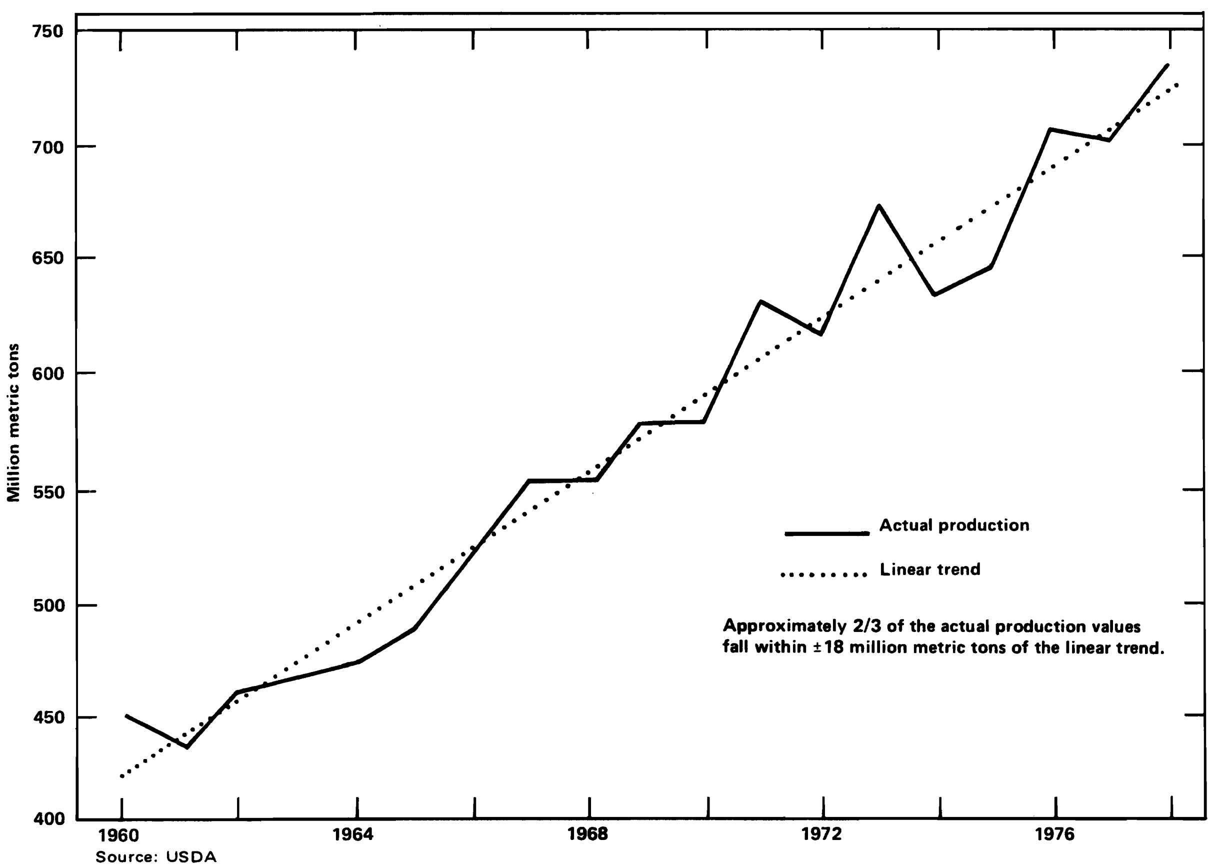

Figure 4. World coarse grain production.

Table 6. World grain prices, average July-June prices for 1976/77 and 1977/78.

Commodity	1976/77	1977/78
	(U.S. dollars)	
Wheat (U.S. No. 2 Hard Winter, 13 1/2 percent)[a]		
Dollars/metric ton	138.03	133.13
Dollars/bushel	3.76	3.62
Wheat (Canadian Western Red Spring, 13 1/2 percent)[a]		
Dollars/metric ton	144.42	143.38
Dollars/bushel	3.93	3.90
Corn (U.S. No. 3 Yellow)[a]		
Dollars/metric ton	119.48	107.22
Dollars/bushel	3.03	2.72
Rice (Thai, White, 5 percent broken)[b]		
Dollars/metric ton	257.33	337.00

[a]c.i.f. Rotterdam.
[b]f.o.b. Bangkok.
Source: Foreign Agricultural Service, USDA.

Table 6 shows some representative average prices for wheat, coarse grain (corn), and rice. For wheat and corn, Rotterdam is the center of international pricing and exchange while Bangkok is the focal point of world rice pricing and trade. Table 7 contains computations of the variability in international prices for these grains net of inflationary trends. The larger values for rice indicate greater instability in rice prices than in corn or wheat prices.

The variations in prices indicated in Table 7 and in production shown in Figures 1-4 are the stimuli for grain reserve proposals. Storage programs aim at smoothing out supplies between years of plenty and years of scarcity, thereby reducing price fluctuations.

Table 7. Indexes of international price fluctuation for wheat, corn, and rice.

Grain	Index of price fluctuation[a] From 3-year moving average	From 5-year moving average
	(percent)	
Wheat	4.1	7.3
Corn	4.8	7.0
Rice	7.0	14.0

[a]Mean percentage deviation from the indicated moving average in 1977 constant dollars for the 1955-77 period.
Source: World Bank.

3. Grain Reserves as a Topic in Applied Economic Research

The international negotiations recently held under the auspices of the United Nations Conference on Trade and Development (UNCTAD) attempted to formulate an interlocked system of national reserve stocks and internationally-agreed principles for inventory acquisition and disposal. The negotiations failed in March, 1979, when agreement could not be reached on total stock size, trigger prices for accumulation and disposal of stocks, and financial aid for developing countries' storage programs. Although this attempt was unsuccessful, the issue is not dead. Grain production around the world remains unpredictable and variable. So the debate will continue. New proposals will surface. The research findings summarized here can contribute to future deliberations on this important topic.Although the creation of a major, centralized, international grain reserve on a multi-lateral or single-nation basis is unlikely, most of the empirical research reviewed and described in this report — and generally available anywhere — deals with the topic as if the stocks were held and manipulated by a single decision-making entity. Even so, this research can provide insight into the issues and relationships critical to decentralized schemes. In principle, a closely linked system of national reserves could perform the same functions and achieve the same objectives as a centralized scheme. Unless the system was perfectly coordinated, the total holdings of a decentralized reserve system would need to be larger than with a single stockpile, for any given level of protection for participants against shortage or market instability. This follows from concepts of pooled risk and actuarially-based insurance and has been demonstrated empirically in some of the studies discussed later. So the results and conclusions of the studies reported here, taken with appropriate caution, can be relevant for decentralized schemes, even though operational details would be different from those explicitly or implicitly assumed in the research.

The Research Inventory

A glance at the bibliography of this report reveals the general character of the available work. Approximately 35-45 items form the core of empirical work on grain reserves in the current international context. Several of these reports display overlapping authorship, and some rely on a single basic model, method, or data base. All but a few have appeared since the latest major surge of interest in reserves began in about 1973 and 1974. Pioneering studies by Gustafson, Waugh, and Reutlinger dominate the earlier work and set the stage for most later efforts [11][15][24].

Most of the available work, and everything listed in our bibliography, was published in English. It is authored mainly by North Americans. Although we attempted to locate other work, it is possible that some significant research on international grain reserves published in languages other than English or in documents not circulated widely was inadvertently overlooked. Work focusing on grain storage questions for individual importing nations or regions was beyond the scope of this study and therefore excluded.

The bulk of this empirical research inventory appears in the mainstream of professional communication in economics and agricultural economics — government bulletins, institutional monographs, journal articles, and mimeographed discussion papers issued by academic departments and research institutions. There is no doubt that the fundamental work behind a number of the listed publications is contained in master's and Ph.D. theses submitted to various universities. No attempt was made to identify and cite this work except as it is discussed and reported in other outlets.

A rough cataloging of author affiliation suggests that about 30 percent of the work was originated by academic economists in U.S. land grant and other universities. Another 20 percent stems from work within the U.S. government, and the remaining 50 percent can be attributed to economists in various other institutions such as the United Nations, the World Bank, the Brookings Institute, the Rand Corporation, and the International Food Policy Research Institute.

Overview of Major Research Objectives and Methods

It is not possible to catalog and state the main objectives and methods of existing grain reserves research in neat categories. However, it is possible to make a few rather general observations about the directions taken and goals pursued by researchers in this area even though they display widely different interests and styles. In the first place, the nature of our selection procedure yielded a group of research reports for which the central thrust is to measure or estimate some or many facets of the real-world grain reserves topic. Although each study does reflect some theoretical framework or foundation, as a group they do not represent a major effort toward new or improved economic or statistical theory. In addition, the studies under discussion are policy-oriented in either a national or international dimension and, therefore, attempt to generate some specific policy conclusions or recommendations.

To a substantial degree, the analytical and statistical methods employed were determined by and linked to the main objectives of the work. There is really no common method of inquiry which permeates the research in this field as in some other areas. Still, some broad classifications are possible. The methodological aspects of the work in this field are not emphasized in this report. Yet a few observations about the techniques of study and how they cluster around the research objectives may be helpful.

One of three, or perhaps four, central objectives are to be found in each of the studies surveyed here. First are studies whose primary goal is a systematic examination of historical experience in order to measure the extent and severity of year-to-year departures from "normal" in crucial variables such as production, yields, prices, trade, and stocks. Such knowledge is then used to provide inferences about levels of grain stocks needed to deliberately offset some of these fluctuations as they may occur in the future. In addition, this kind of analysis also is used to help assess the risks (in a probability sense) associated with stockpiles of various sizes. Most studies of this type emphasize supply availability or food security objectives of storage rather than price stabilization.

Trend and time series analysis is most commonly employed in these historical studies. By fitting trends, moving averages, or more complex time series calculations to actual historical data, some approximation of "normal" or systematic behavior is achieved. Then further statistical analysis is conducted on the observed random or unsystematic fluctuations away from these reference points. The Waugh study mentioned earlier is a prototype of this general category [15]. Others in this category are discussed in Section 4.

Second are studies designed mainly to evaluate the behavior of one or many particular programs or proposals for a grain reserves system. Here, for example, the operating rules and size of the stockpile to be acquired and manipulated are given either by assumption or by someone outside the investigator's purview. In these studies, the investigator typically generates new or employs existing estimates of demand and supply relations to make the evaluation and test the behavior of the system. The criteria against which the outcomes are assessed vary widely within this class of studies.

Many of the studies in this category rely upon the techniques of econometrics and simulation. Demand, supply, and trade functions for the commodities under consideration are estimated by econometric methods — simple or very complex. Historical data is typically the basis of analysis. Then a complete (closed) model is formed, and repeated random shocks are applied to the system to reflect the impact of unpredictable influences, mainly weather. (This is often called the Monte Carlo method of analysis.) The outcomes of this simulation process are then summarized and interpreted. Average levels and dispersions of prices, consumption, trade, inventories, etc. are studied with and without specified hypothetical grain reserve programs in operation. An important feature of many simulation studies of grain reserves (and to some extent of trend analyses) is to establish and measure various tradeoffs between variables such as stockpile size, costs, protection against shortages, price fluctuations, and benefits for various economic groups. The previously-mentioned Reutlinger study is an early example of the econometric-simulation category [24]. Section 5 contains summaries of the others in this general grouping.

Studies in the third category have as their main objective the design of an "optimal" program of grain reserves. The "optimal" stock size for a particular time (or an average of optimal stock sizes over several years) and the "optimal" operating rules are identified relative to some specific criteria which are laid down in advance. These criteria generally emerge from maximizing a function assumed to reflect the objectives of the operating institution and/or society at large. Here, a crucial element of the research involves the precise specification of these objectives in a way that leads to an identifiable solution. The theoretical principles of welfare economics are very important for this class of studies since they provide the basis for translating abstract social goals into specific economic criteria subject to empirical analysis.

Econometric methods and various programming techniques come into prominence with this class of studies. As with the simulation category, econometrically-estimated functions typically are employed as the underlying behavioral relations in the context of a complete economic model. Using the model's equations, objective functions are formulated mathematically using the tools of welfare theory. The objective functions are then maximized subject to the constraints of the underlying model, which includes a grain reserve component. These computations often involve an iterative means of calculation commonly called activity analysis or dynamic programming. Because the optimal method delivers the single reserve stock program which maximizes the specific objective function selected, the calculation of trade-offs and assessment of alternative operating rules is not easy with this approach. The foundation of this approach in the reserve stock area was formulated by Gustafson in 1958 [11]. Other studies stressing this approach are described in Section 6.

A fourth objective which is highly important for some studies and which overlaps the other three is the testing or elaboration of particular research methods or statistical techniques. Here the methodological approach is foremost, and its empirical application to grain reserves is distinctly secondary. Such emphasis on methodology is not uncommon in economic research, especially in areas where estimation problems are complex and wide agreement among researchers on techniques does not exist. We have included studies emphasizing method and technique only to the extent that they shed empirical light on the grain reserves issue from the viewpoint of one or more of the other main objectives.

4. Trend and Time Series Analyses

This section and the next two contain brief discussions of approaches and findings from the major empirical studies on grain reserves. Since the focus is on results, research techniques are not described in detail. In most cases, the results presented are illustrative because most of the studies examine many alternative scenarios reflecting various policy goals, alternative assumptions about future production, consumption, and costs, and specific impacts on different economic and political groups. Some studies recommend specific stock levels or storage policies. Others attempt to develop guidelines for operating stock programs or for evaluating impacts of various stock proposals.

Results are commonly stated as probability or confidence intervals since the unpredictability of the future makes highly specific statements inappropriate. Also, it is usually assumed that grain reserve schemes will not provide for very rare expected events. Thus storage plans typically are designed so that perhaps 9 out of 10 or 99 of 100 shortfalls in grain production will be covered by grain stored from previous crops.

Conclusions from all studies depend upon the assumptions made by the researchers and the restrictions inherent in the analytical methods. Key limitations and assumptions are mentioned in the text that follows.

Waugh [15]

This pioneering study of U.S. grain reserves done by USDA in 1967 reviews past agricultural programs, policies, and thinking about managed storage as a mechanism to achieve national goals. The empirical findings are offered to aid decision-making on quantitative goals for reserve policies. Estimates are given for wheat, corn, four feed grains, rice, and cotton. They are based chiefly on deviations from trend production. The author reports, but does not formally link together, correlations among good and bad crops in several nations, probabilities of successive crop failures in the U.S., and correlations among U.S. production of substitutable grains. The following grain reserve stock levels are suggested by the author as appropriate for the period around 1967:

	Million metric tons
Wheat	15.0-17.7
Corn	20.3-25.4
All feed grains	31.8-40.8
Rice	0.4-0.5

The main contributions of this study are its scope in delineating the background and relevant issues and its straightforward attempt to make empirical estimates useful to policy-makers.

Bailey, Kutish, Rojko [16]

Although this USDA analysis views the grain reserve issue mainly from a U.S. perspective, some global results are achieved. The commodities under consideration are wheat, coarse grains, and rice. Positive and negative deviations of grain production from historical trends were taken as indications of the world's ability to accumulate stocks in some years and the presence of shortages in others. Several alternative measures of world and U.S. grain shortfalls were compared to both actual and possible U.S. stock accumulations to determine their adequacy and costs over a 20-year period. Results under one set of assumptions indicated that if the U.S. had maintained stocks at 10 percent of production during the 1950-69 period, 162 of 179 million tons of aggregated world deficits could have been met. In 1972, 10 percent of production was 21 million metric tons. No storage plan is proposed. The study provides rough indications of the magnitude of grain supply problems and the potential for easing them.

Steele [17]

This USDA paper is both a discussion of the general policy issues surrounding U.S. and global grain reserves and a report of some empirical estimates of reserve requirements. World production and trade of major importers and exporters are examined for the 1960-73 period. Deviations from trend are calculated and then used to estimate potential shortages that grain reserves could fill. Estimates were made for wheat, rice, and coarse grains at three levels of protection — covering 68 percent, 95 percent, and 100 percent of the shortfalls which actually occurred in 1960-73.

When variability of world production and trade was examined, the USSR emerged as the major source of fluctuation in wheat markets and India in rice. Variability in coarse grain production and trade is less dramatic and less dominated by a single nation than wheat and rice. However, variability in coarse grain export supplies depends heavily on fluctuations in U.S. production.

A range of stock estimates is given, varying according to which countries are included as potential recipients. For example, if exporters and the USSR are excluded from the wheat analysis, 95 percent of the remaining world shortfalls could be met with a 12-million-ton reserve. (The rationale for possibly excluding exporters is that they could likely manage their own grain needs without depending upon a global reserve.) This compares to 29 million tons if all nations are included. Similarly, excluding India from the rice computations reduces the needed world rice stock from 18 to 9 million tons, to cover 95 percent of crop shortages. For coarse grains, excluding exporters reduces the stock requirements from 34 to 14 million tons.

Projected total world stock levels for 1980 needed to cover 68 percent of potential shortfalls are 20 million metric tons of wheat and 22 million metric tons of coarse grains. For 95 percent protection, the stock levels are 43 million metric tons of wheat and 48 million metric tons of coarse grains.

Casley, et al. [1]

This article from FAO presents a method for estimating cereal stock requirements for a single nation or a free-trade region of several countries. The model requires estimates of production growth rates, variation of output, and demand growth rates. Indexes to measure instability (variation) and growth rates of grain production in the 1952-72 period were calculated for 126 nations. These indexes for the major grain importing and exporting nations are:

	Instability index	Annual production rate of growth
United States	9	+2.6
Canada	28	+1.6
Australia	43	+4.7
Soviet Union	20	+3.3
India	8	+2.7

A high instability index indicates more variable production than a low index and is attributable mainly to climatic differences.

The production growth rates can be used together with estimates of demand growth to calculate desirable levels of stocks for individual countries without trade adjustments. Some examples are given with illustrative data, representative of an LDC, to show how a nation's stock requirements might be calculated with the model. No rules are given for operating a program. The required beginning stock can be determined if some specific probability of success (probability that the stock will not be depleted in a specified time period) is assumed. On the other hand, the probability of success can be generated for any predetermined beginning stock level. A high index of instability yields a larger stock requirement than a low index. Thus nations with highly variable grain production need larger stocks than those with more stable levels of output.

Committee on Commodity Problems FAO [2]

Three simple methods were used to estimate historical magnitudes of shortfalls in world grain production between 1955 and 1972. These FAO estimates were intended to indicate desirable stock levels for the future. To determine the level needed as reserve or safeguard against production failure, an estimate of working stocks was made. These analyses assumed that the low ending stock levels for crop year 1973/74, when prices soared, consisted only of working stocks.

The estimates of working stocks and total stocks (working plus reserve stocks), as percentages of consumption, are:

	Working stocks	Total stocks
All cereals	12	17-18
Wheat	17	25-26
Coarse grains	11	15
Rice	10	14-15

At 1973/74 consumption levels, total "safe" carryover of all cereals would have been 225-230 million tons, 65-70 million tons above working stocks.

Trezise [45]

In this Brookings Institute monograph of 1976, the author reviews the history and politics of international grain reserves and estimates requirements to meet likely production shortfalls. Production and consumption trends and deviations are calculated for groups of the major importing and exporting nations for 1960-74. The trends are projected to estimate reserve requirements and potential supplies for 1976-80. To cover all but extreme shortfalls, 22-31 million tons of wheat, 28-34 million tons of coarse grains and 14-16 million tons of rice would be required. If only famine relief in South Asia is covered, requirements range from 18 to 20 million tons. These estimates are based on 95 percent probabilities. That is, there is only one chance in 20 that a shortfall would exceed the specified reserve levels.

5. Simulation and Other Experimental Analyses

World Bank

A series of studies by Reutlinger and others employ a stochastic simulation model to evaluate impacts of a variety of food grain reserve schemes [24][25][26][27][28][29][30]. These models assume that grain is added to a buffer stock whenever total supply exceeds a specified level and withdrawn whenever supply falls below a specified level. Food security protection is the goal. It is achieved by assuring adequate grain to stabilize consumption. In most cases, the buffer stock is used only in response to extreme circumstances. By simulating 300 runs of the model for 30 years, Reutlinger estimates the degree to which the buffer stock policy can reduce the variability of consumption, prices, and other variables. The initial simulation models were of the world wheat economy. Subsequent models have focused on an individual developing country, especially concerned about protecting its poorest consumers, which has options both to hold buffer stocks and import.

Worldwide grain market. Benefits to producers, consumers, a storage agency, and the total world economy (the sum of all three sectors) were computed for several storage capacities, two storage rules (both of which are quantity determined), and three assumptions regarding the responsiveness of world grain demand to price changes. All estimates include handling and operating costs of a storage authority while costs of initial investments in storage facilities were included in only some analyses. The model presumes free international trade and zero transportation costs. Supply and demand parameters were taken from analyses of wheat data for the 1960s and early 1970s. Demand was presumed to be more inelastic at prices above the mean than at lower prices. The various reserve options were evaluated in terms of their costs and of how well they succeed in achieving a stabilization goal. Detailed basic analyses were conducted for total wheat storage capacities of from 5 to 30 million metric tons with some additional calculations of up to 50 million metric tons.

Costs exceeded benefits for producers, the storage agency, and the world as a whole at levels of protection considered satisfactory. This implies that fully adequate grain storage cannot be justified solely on the costs and benefits measured in this analysis. The shape of the demand curve strongly influences these results. The variance of costs and benefits was large; thus storage is risky, and the storage agency loses money most years.

Total costs increase sharply as storage capacity increases. However, costs are less or benefits larger, the more inelastic demand was assumed to be (–.10 instead of –.25, for instance). This occurs because there is an opportunity for profitable resale in years of short supply when inelastic demand causes higher estimated grain prices. Lower net storage costs make storage more profitable. At any given storage capacity, costs are greater when a wide band separates the quantity levels at which stocks are acquired and released than when that band is narrow. This results from reduced consumer benefits and greater costs to the storage agency which are not offset by lower costs to producers. However, at a given chance of running out of stocks in years of crop failures, a wide band requires less storage capacity than a narrow band. With a narrow band, stocks are released for modest shortfalls, leaving less for major crop failure. Thus, a wide quantity band provides less costly protection.

In general, consumers gain and producers lose from stocking activity within this model. Changes in benefits for the two groups tend to move in opposite directions. For instance, changing from a wide to narrow quantity trigger band increases consumers' gains and increases producers' losses. Estimated costs and benefits change greatly under different values of demand elasticity. Thus these overall results depend crucially upon the elasticity estimates or assumptions.

With the assumed storage costs, storage is a losing business for inventory holders at stock levels providing high food security protection. To meet these protection goals, grain must be held for long periods. The consequent high costs do not tend to be covered by an equivalent price rise. Thus, it is unreasonable to presume that unsubsidized private storers would adequately meet food security goals.

The ability to meet consumption goals increases as storage capacity increases, but at a decreasing rate. Thus costs rise sharply for each additional degree of protection sought. At a given storage capacity, a wider band governing stocking activity provides more protection than a narrow band. This is because, when the band is wide, grain is held until the world harvest is extremely poor. With a narrow band, grain is released for modestly short crops, possibly leaving inadequate supplies for extremely short years.

It was observed that stocks reduce costs of emergency food aid for poor nations which suffer unforeseen food shortages. Without stocks, grain purchases for aid increase prices when crops are short, making the needed grain more costly than if stored grain were available. In one analysis, anticipated demand for food aid was added to the commercial demand function. This caused increased benefits to flow from grain storage to the world's consumers, inventory holders, and the economy generally, while increasing costs to grain producers.

Separate calculations of gains and losses were made for various country groups. Generally, exporters lose and importers gain from stockpiling schemes. As above, estimates are quite sensitive to the shape of the demand curve and the value chosen for its elasticity — the more inelastic, the greater the relative benefits to importers.

An LDC grain market. Several papers within this group evaluated a national government-operated grain storage program in terms of costs and likely success in meeting the nation's food security goals. Some also evaluated interactions among domestic storage programs, food subsidies for low-income consumers, price supports for grain growers, and controls on imports and exports. Benefits and costs to producers, consumers, the government (from storage activity, tariff revenues, and subsidies to the poor), and the whole economy (sum of the above) were calculated for various storage capacities, storage rules, subsidy programs, trade policies, and assumptions regarding production variation in the LDC as well as world price fluctuations. Specific assumptions also were made about world demand response to wheat price changes. Demand in the LDC is the sum of demand by low-income and high-income consumers. Demand by low-income consumers, and thus total demand, is systematically altered by subsidies to the poor in the analysis. When prices are above a specified level, the government subsidizes grain purchases.

In this single-country analysis, most of the stabilization and cost effects were a function of available storage capacity, width of the band for acquisition and release, welfare trade-offs between consumers and producers, and the operation of a global buffer stock. However, when poor consumers were guaranteed at least minimal consumption levels no matter what, consumers in the aggregate lost from storage. Changing the width of the band governing storage operations had little impact on the general results. Storage costs to the government and subsidies to the poor tended to be offsetting — when one rose, the other fell.

Opening the country of concern to trade has tremendous potential to stabilize consumption. It is less costly than storage, but it destabilizes foreign exchange transactions. Storage with trade provides more stable supplies and prices than does either alone.

One study in this group investigated three alternative policies for managing a buffer stock in India over a five-year period. An initial 10-million-metric-ton stock was assumed to be available. Estimates of world price variation and Indian production variation were made from historical data. Various levels of consumption and financial limits on importing grain were examined.

It was found that a policy which varied import quantities according to world prices (*i.e.*, allowed stocks to build when imports were relatively cheap) met goals of consumption stability and cost minimization better than policies designed to equalize annual imports or to seek self-sufficiency in wheat.

If import expenditures are permitted to cover unusually large production shortfalls, target consumption levels can be met virtually every year. The expected import quantity needed to meet such emergency situations is reduced if annual exchange limits for imports are high enough for the nation to maintain some stocks continually.

This analysis suggests that stock capacities above 10 million metric tons for India generate very high costs. Capacities larger than 10 million metric tons are warranted only if low-priced concessional wheat imports are available periodically. Moreover, the assumption that 10 million metric tons of initial stocks are available naturally generates results which are more favorable than if no initial stocks are assumed to exist.

Tweeten, Kalbfleisch and Lu [5]

A simulation model of the 1970 U.S. wheat sector was developed at Oklahoma State University for evaluating three approaches to reserve management. For most variations, 4,000 runs were made. The first reserve policy assumed that all inventory was privately held and, therefore, determined by market forces. The second and third assumed public intervention to acquire and dispose of stocks according to either price or quantity rules. Stock management under the quantity rule approximated an optimal mechanism for determining storage levels. The optimizing criteria involved minimizing both social and storage costs.

Four supply situations were investigated. For all four, yield was a random variable, but they differed in how acreage was determined. One assumed a free market; the others assumed that acreage was policy-determined to achieve three different target carryover levels. Three demand relationships were specified: (1) all domestic consumption except feed; (2) domestic feed use; and (3) exports. The export relationship included a random term. The reserve stock policy determined the demand for stocks.

The policy objectives evaluated were: the level and variation of production, consumption (food, feed, and export), stocks, prices, net and gross farm income from wheat production, and two measures of net cost or net loss (welfare costs including and excluding storage costs).

The authors concluded that the price-rule storage management policy may be preferable to the others examined because it provides more adequate levels and stability for prices, farm income, and costs. The optimal rule required more difficult and sensitive judgments, in the authors' opinions. However, they emphasized that none of the rules is superior by all criteria. Wider price bands are found to reduce average price and income levels and to increase their variability. Wider bands also lead to lower stocks, thus costs. In models with low carryover targets, wider bands raise chances of no stocks being available if needed. If stocks are managed, policy-controlled wheat acreage is preferred to market-determined acreage so that variance in prices and incomes and the chance of no stocks are reduced. Although the specific findings of this study are obsolete, it was a forerunner for subsequent simulation analyses.

Ray, Ericksen, et al. [6][7]

Ray and associates at Oklahoma State University tested U.S. reserve stock proposals together with farm price and income support programs in a simulation model designed to evaluate U.S. commodity policies in 1975 and 1976. The grain reserve proposals assume deliberate government policy to manage stocks for stabilizing the market and for assuring supplies when crops are short. Impacts on farm incomes, level of production, size of carryover stocks, ownership of stocks (government or farmer), and price stability were measured.

Wheat, feed grain, soybean, and cotton markets were analyzed. The analytical models contain estimated supply and demand relationships, including random terms to account for unpredictable variations in yields and exports. Historical correlations among yields of the four commodities and among their exports were built into one experiment. No other intercommodity relationships were analyzed.

The investigation included various basic loan rates, target prices, and triggers for stock activity. Some of the signals to trigger reserve stock action combined carryover levels with prices. Some proposals linked production control programs (loan rates and acreage set-asides) to past (or expected) stock levels. One variation compared two different crop loan maturity lengths.

The model gives empirical results as expected values and variances for the policy objectives listed above. Results are reported annually for a five-year period (1975-79 or 1976-80) and as five-year averages.

The following results were obtained when stock management programs were added to existing U.S. farm price and income programs: (1) prices rose and became more stable; (2) exports fell as a result of the price rise; (3) set-aside was used more often, leading to more variation in acreage and quantity produced; (4) the value of production and farm income rose and became less variable; (5) stocks accumulated and became more variable yet total government costs fell because of smaller income support payments. The wheat model with stock management generated an average total carryover of 13 million metric tons (of which 2 million metric tons were CCC stocks). The comparable figures without a stock program were 11 million metric tons and 278,000 metric tons, respectively.

Prices were higher when the crop loan maturity was set at 10 months rather than 30 months. The higher prices led to higher farm income, higher consumer food expenditures, and lower exports. In turn, these changes increased stock levels and set-aside acreages, causing higher government costs and lower output.

Generally, the research shows that stock management can be utilized effectively in combination with the existing tools of U.S. farm policy. The model demonstrates trade-offs among the conflicting policy goals. International implications of this research are not drawn explicitly, but the general effects on prices and exports are indicative of trade impacts.

Sharples, Walker, et al. [18][20][21][22][23]

These USDA researchers approached grain storage issues mainly from a U.S. policy perspective. They used simulation techniques to examine the U.S. wheat market and, in one study, linked the U.S. wheat, feed grain, and livestock sectors together. Their reports, published in 1975-77, review the arguments favoring and opposing government stockpiling and discuss operational principles for stocking programs and ways to evaluate costs and performance. The analytical results focus on the impact of publicly-controlled buffer stocks on the level and variability of: (1) U.S. farm prices and incomes; (2) production; (3) domestic consumption; (4) trade; and (5) government costs. Some results are interpreted in an international context, drawing implications for world prices and estimating impacts of U.S. stock programs on importing nations.

They evaluate stock schemes operated under price rules, quantity rules, and an insurance procedure designed to protect only against very high prices/short crops, but not against low prices. One particular price rule analysis utilized the price and income guarantees (the loan rates and target prices) of domestic farm programs. The guaranteed floor prices (loan rates) were assumed to be the stock procurement price. It was presumed that income maintenance payments to producers directly affect government costs but not stockholding activity or the wheat market generally.

Simple formulations were used to represent the supply and demand relationships in the commodity markets. Variability of yields and exports were introduced as random elements. Results are stated as expected values and in terms of likely variation. Export variability caused most of the variation. Results are simulated for a seven-year period (either 1975-81 or 1976-82) and reported both as annual values and as averages over the seven years.

Under the stock program with price rules, the basic analysis identified price levels such that sales and purchases balanced over the seven-year period. A higher level of acquisition and release prices (with no change in the width of the price band) leads to: (1) higher average levels of government stocks and a smaller chance of zero stocks; (2) higher costs for stocking but lower total government costs (total costs are lowered because the higher price level reduces deficiency payments to producers more than storage costs increase); (3) less domestic use and smaller exports because the market price is higher; (4) less variability of prices, production, and producers' incomes; (5) more variability of exports since more stocks are available to meet export demand in peak years. A price range lower than that identified in the basic analysis increases both price variability and the chance of having no stocks. But it lowers costs.

Raising the guaranteed income level for growers increases government costs and producer incomes and lowers the variability of incomes. In this model, government costs can be reduced by supporting farm incomes with price support and storage programs instead of with government payments to farmers. Lower payments more than offset higher costs of stocks.

One study examined a quantity rule for stocking activity. It related U.S. reserve stock activity to changes in wheat and feed grain production in the rest of the world. Buying and selling by the U.S. grain reserve were assumed to occur when non-U.S. production deviated from trend by at least 2 percent in one experiment and 5 percent in another. Under the 5 percent rule, little U.S. stock action was precipitated so little impact on prices occurred. Under the 2 percent rule, U.S. action was generated in approximately one year of each two, reducing price variation somewhat.

These researchers considered the quantity rule more difficult to operate than the price rule because data needed to make operational decisions are difficult to obtain in a timely way. And, they concluded, this rule was less effective for stabilizing markets.

Four different levels of initial stocks also were examined. As the size of the opening stocks was raised: (1) average market prices fell and their variance was reduced; (2) farm income fell; (3) benefits to foreign and domestic consumers increased; and (4) higher and more variable government costs occurred.

To test the impact of freer trade, price elasticities of export demand of –1.0 and –5.0 were examined. With the higher elasticity and no stocks, the same price stabilization was obtained as with the lower elasticity and a 15-million-metric-ton stock. In other words, freer trade (causing higher demand elasticities to exist for international transactions) could reduce the need for stocks to stabilize prices.

This model, in which demand and supply respond to price, was compared with another without any price response at all. A 15-million-metric-ton reserve, analyzed with the price-responsive model, gave the same protection against production shortfalls as a 24-million-metric-ton reserve in the model with no price responses.

Rojko [19]

This short 1975 paper from USDA examines the relation between expected levels of grain carryover and prices in the following period. Four situations are examined — a cereals economy and a grain-livestock economy each with and without guaranteed price floors.

A test of the model with U.S. data for wheat and corn supports the hypotheses that prices rise rapidly when low carryover stocks are anticipated. The resulting price rise is less severe for feed grains than for food grains. The latter result occurs because adjustments are possible in the livestock sector as animal numbers are reduced and other livestock feeds are substituted for grains. The author argues that the price impacts of low stocks encourage speculative market manipulation, adding further instability to the grain market. Grain reserves can deter such activity and alleviate the severe consequences to consumers of grain shortages.

Trapp and Thompson [44]

An agricultural sector model was used to examine the relationship between government grain stock levels and the impact of three levels of grain exports on U.S. crop and livestock production and prices. This Michigan State University study is part of a larger project which investigated impacts of the large grain exports in 1972. The econometric-simulation model allows for interaction among the wheat, feed grain, soybean, and livestock sectors. Estimates were generated from 1952-71 data. The study evaluated an increase in wheat exports of 16, 6, and 2 million tons when the government held wheat stocks of 20, 10, or 0 million tons. (In 1972, U.S. wheat exports rose about 16 million tons, while government carry-in stocks were 23 million metric tons. Stocks then fell to 9 million tons at the end of the year.) Comparable ranges of export and stock levels for feed grains and soybeans also were tested.

The main finding of this work supports the widely held belief that medium and large increases in exports affect prices and subsequent production more when stocks are low than when they are large. Wheat prices increased four-fold under the scenario of a large export increase when stocks were low. Impacts on corn and soybean prices were less dramatic because of their greater demand elasticity. These price increases depressed livestock production in the model but stimulated future grain production.

Zwart and Meilke [46]

After estimating an econometric model of the Canadian and "rest-of-world" wheat economies, these researchers from the University of Guelph (Canada) tested several variations of three grain reserve storage rules by simulation experiments. The model was estimated with 1950/51-1974/75 data and reported in 1976. Simulations were run for 12 years (1974/75-1985/86) with 50 replications to select random shock terms for the demand, price, and acreage equations. The storage policies evaluated were a Canada-only scheme and a scheme in which Canada shared in a world grain reserves plan. For the first, the rest of the world was assumed to follow historical storage practices. In the latter, Canada was assumed to hold one-third of world wheat stocks.

The storage rules investigated were price only, quantity only, and one combining price and quantity values. Values were set to represent flexible and inflexible storage policies with respect to price and quantity (quantity being production plus carry-in stocks). The stocking rules do not operate with fixed target ranges. Instead they are functions which determine end-of-year stock levels dependent upon prices and/or production and carry-in stock levels. In total, eight storage rules were compared with a no-storage policy and with a continuation of historical storage practices. Comparisons were made in terms of expected values and variances of stock sizes, prices, benefits to consumers and producers, and storage costs. Average world stock sizes estimated from the world analysis range from 20 to 24 million metric tons under the storage rules, while under a continuation of historical practices stocks were estimated to average 32 million metric tons.

None of the rules was superior against all criteria and none generated benefits that exceeded costs. The greatest differences among rules were in their impacts on variances — average or expected values differed little. The empirical results do suggest some of the trade-offs between different groups in the world wheat sector to be faced in policy making. In addition, this study shows that a world scheme can have opposite impacts on economic groups in an exporting nation than for the same groups in the rest of the world. For example, highly price-responsive storage policies are best for stabilizing world producers' revenue, but are destabilizing for Canadian producers.

The storage rules tested differed more in their impact on price stability and consumer surplus than on producer welfare. For the world as a whole, producer revenues are stabilized more by a price-stabilizing storage scheme than by a quantity-stabilizing scheme. On the other hand, the most stability for consumers comes from storage rules that combine price and quantity triggers. The authors then conclude that the mixed rules seem to be the best overall for seeking benefits of stability for producers and consumers. They argue further that effects on individual nations cannot be assumed from global analyses.

Levis and Ducot [40]

The capacity to evaluate a variety of grain storage policies and regulations was built into a large dynamic simulation model of the U.S. food sector called AGRIMOD. It is a comprehensive model, covering a wide range of economic activity from agricultural production inputs to food consumption. The model generates estimates of annual production and carryovers for wheat, rice, corn, other feed grains, and six other commodities or commodity groups. It has been evaluated (validated) against 1956-74 historical data. It is reported to be capable of analyzing impacts of changes in external variables (*e.g.*, public policies of technological changes) for a 15 to 20-year period.

Options are available to test grain storage reserves acquired and released by price or quantity triggers, or a combination of both. An interaction of public grain reserves with commercial carryovers also may be incorporated. To date no empirical analyses of reserve schemes have been reported.

Brzozowski [32]

A system dynamics simulation model was constructed by the Systems Dynamics Group at Dartmouth College to analyze long-run relationships in the U.S. wheat sector. Such a model permits consideration of long-term as well as short-term impacts of government decisions regarding grain reserves, export policies, production control programs, and the like. This research reported in 1976 analyzed consequences of the 1972 and 1975 wheat sales to the Soviet Union and draws implications for future policy decisions in light of interaction among programs to promote export sales, to prevent rising consumer prices, and to maintain farm incomes.

This particular model revealed underlying cycles of approximately 4-1/2 years in wheat production and prices. The cyclical behavior results from the estimated lagged production response to price changes. When prices rise or fall, time is required for farmers to make adjustments to expand or contract their wheat output.

Random weather variations add instability by affecting domestic and foreign yields. The latter translates into unstable demand for U.S. exports. Both government and private storage offset supply and price fluctuations to some extent by removing grain from the market when prices are low and supplying grain to the market when prices are high. However, this buffering action of stocks also delays production response in the model because it moderates price changes.

The analyses of the large 1972 and 1975 grain sales to the Soviet Union reveal disparate results. The 1972 sales came to a low point in the production cycle so it caused severe price oscillations. After stocks were depleted, output could not expand enough to fill the gap. In contrast, the 1975 sale stabilized the market because inventories were large and output was high.

The author concludes that because the goals of maintaining farm income, preventing consumer price increases, and assuring supplies to foreign countries are in conflict with one another, cross impacts need to be considered. Moreover, impacts of each program for the entire wheat sector should be examined before any stock policy is implemented.Otherwise there may be unforeseen and undesirable consequences. In addition, proposed policies should be examined in light of the cyclical behavior of the wheat economy as revealed by this research — program impacts can be expected to differ at different stages of the cycle.

Cochrane and Danin [34]

These University of Minnesota analysts formulated a world model for wheat, coarse grains, rice, and all grains, and a U.S. model for wheat to evaluate several stock decision rules for a 10-year period. The principal focus of this 1976 study is on stock size relative to price stabilization, associated with a specific probability of success. Four price-bounded decision rules (one with an upper quantity limit) and one optimal stocking rule were investigated. The optimal rule generates stock changes (additions or sales) to minimize price instability.

After initiating a world reserve, stocks averaging 38 to 57 million metric tons of all grains (after five and ten years, respectively) would keep prices within 10 percent of the target price level, four years out of five. This conclusion assumes that grains are basically interchangeable in use.

A stock program to stabilize the U.S. wheat market would reduce price variability under the assumptions of this analysis. Yet substantial price variation remains. Reducing variation more than that provided by a 10 percent price band governing stock activity requires very large stocks.

Results depend crucially on the price elasticity of demand. If the mean elasticity is –.2 instead of –.1, and the demand curves are linear, less price instability is generated by market forces. Thus the need to reduce price fluctuations is less. Changing the size of initial stock holdings has an impact on price stabilization only for the first few years after a stock program is begun. Wider price bands to trigger stocking activity reduce needed stock levels, hence costs.

Rand Corporation [8][9][10]

Studies by Rand researchers, Stein, Keeler, and Smith, analyzed grain storage policy for the White House Council on International Economic Policy and for the National Commission on Supplies and Shortages. These reports from 1977 review existing studies from a U.S. policy perspective, focusing on: (1) resource costs of adding stability to grain markets; (2) the relationship between privately and publicly owned stocks; and (3) the distribution of costs and benefits arising from government participation in grain storage. In their view, these three points are essential for policy decisions and have received inadequate attention in the literature.

Their analysis is based on logical argument and the assessment of findings from one study of theirs and studies of others. They conclude that price stabilization resulting from storage is beneficial, but that storage above that provided by private firms incurs costs that exceed economic benefits. In their view, such storage can be justified only on the basis of non-market externalities arising from international and domestic considerations. They argue further that profitable government storage replaces private storage on a one-to-one basis and that nonprofitable government storage replaces some private storage, but less than ton-for-ton. To avoid the substitution of government for private stockholding, private storage could be subsidized.

Other conclusions agree with general theoretical findings that most benefits accrue to sectors which cause price fluctuations and to those most responsive to prices. But they cite evidence to dispute the hypothesis that grain prices are more inelastic at high prices than at low prices. Finally, it is pointed out that storage programs to stabilize markets may raise or lower average prices, but it is uncertain which result will occur. Moreover, the welfare consequences of raising or lowering price levels may outweigh those stemming directly from stabilization.

The empirical study conducted at Rand investigates: (1) the use of government subsidies to private storers as a means of raising wheat storage above market levels, and (2) consequences of reducing export variance. Simulations for a 50-year period with 100 replications are used to calculate present values of costs and benefits. Average carryover size, storage and subsidy costs, export sales, domestic consumer, national and world welfare, and the variance in market prices are estimated. Wheat supply and demand parameters for 1979 are taken from Sharples and Walker's work [18].

The effects of 15-cent and 30-cent-per-bushel storage subsidies are tested. The lower rate approximates the physical storage costs while the latter also covers opportunity costs. Opportunity costs are assumed to be costs of investment in grain storage. These subsidies are compared with no storage and fully-private storage situations.

From a no-storage situation, private storage reduced the standard deviation of prices by about two-thirds. An additional 15 percent reduction was achieved by the 15-cent subsidy. An additional 39 percent reduction was achieved by the 30-cent subsidy. The smaller subsidy raises the average size of carryovers about 40 percent. The size increase with the larger subsidy is 170 percent. Average wheat carryovers by the private sector are:

Subsidy per bushel	Million metric tons
None	4.7
15 cents	6.6
30 cents	12.5

Stabilizing prices *via* storage reduces export earnings because high prices and high exports tend to be correlated as do low prices and low exports. Domestic consumer welfare is increased with price stabilization, but national and world welfare are decreased because the storage costs and loss of export earnings for the U.S. offset consumer gains.

Two levels of reduced export instability were tested. One reduced the standard deviation of exports by 25 percent and the other by two-thirds. These two situations resulted in nearly the same degrees of price stabilization as did the two levels of storage subsidies. If export variation could be reduced, consumers would benefit more than they would from storage subsidies because costs of building and maintaining stocks are avoided.

Eaton, et al. [35]

In this 1976 study, a multiobjective linear programming model is employed to generate tradeoff curves between reserve stock sizes and food security targets at various levels of reliability (the probability that the target will be achieved). The major premise is that the three goals conflict with one another. To improve the level of one, another must be sacrificed. Findings are presented as an aid to decision-making, not as a policy prescription or a set of operating rules.

The study cited here, which was developed from Eaton's doctoral dissertation research at Johns Hopkins University, employs a variety of sophisticated analytical procedures. Grain production for 1975-2000 was estimated from 1960-74 data. Then the sizes of a reserve needed to meet a range of food security goals were generated.

The model is used to evaluate world grain storage requirements, assuming free trade and perfect substitution among grains. Although these are recognized as unrealistic assumptions, they permit estimation of a lower bound for stock requirements. A range of possibilities is presented, allowing statements of the following type to be made: "55 million tons are needed to meet a food security target of 98 percent of trend production, if an extreme production shortfall occurs. The probability that this target will be met over a 26-year period is 94 percent." A graph in the paper gives an easily interpreted presentation of how much security or reliability must be given up to achieve lower costs *via* smaller reserve stock holdings.

Taylor, Sarris, Abbott [43]

These reseachers review and discuss the political and economic aspects of grain reserve issues and proposals in a study published by the Overseas Development Council. Reserve stocks for emergency relief, continuing food aid, and market stabilization are covered. Their empirical work analyzes a stabilization stock scheme. They develop and estimate comprehensive, independent models of the international wheat and feed grain markets. They then apply simulation analyses to evaluate impacts of international buffer stocks for each. Their purposes are "to examine the allocation of costs and benefits to various groups, and the feasibility of an international reserves scheme."

Demand, supply, and export, or import functions are estimated (or assumed, if data are inadequate) for 19 countries and regions. The functions are then aggregated to generate international prices and trade flows. An international agency is assumed to operate a stock program to stabilize the market. Acquisition and release are triggered by prices.

Simulations were run for 20 years, beginning in 1974, with 200 runs per year to select random terms for the trade and production equations. The stock program operated in one set. Another set without a stock program was run for comparison. Although only one stock program was examined, results were tested for sensitivity to changing the width of the price-triggering band and to changing storage capacity. Results are reported as means and standard deviations, averaged over the 20 years, for each of the countries or regions studied.

The authors conclude that an international stock of wheat with a 15-million-metric-ton capacity would provide "reasonable" price stability. The stock would be in addition to working stocks, estimated at 38 million metric tons. Reasonable price stability is presumed to limit the occurrence of prices greater than 140 percent of the mean to one year in twenty. The ability to achieve additional stability falls rapidly as stocks are enlarged. Thus the cost of more stability, *i.e.*, larger stocks, accelerates rapidly. In general, exporters lose while importers gain from the stocking activity. If the price band is widened, differences diminish between benefits for exporters and importers.

Results for feed grains differ from wheat because of their greater demand response to price. In general, stabilization activities transfer gains from feed grain consumers to producers; hence, from importers to exporters. Thus, stocking programs for feed grain and wheat together partially offset negative intercountry impacts for either alone.

International Food Policy Research Institute (IFPRI)[4]

A food insurance scheme for developing countries was analyzed with an economic simulation model by Konandreas, Huddleston, and Ramangjura. Total cereal demand and production were estimated for individual countries which together account for more than 40 percent of world wheat imports. Country estimates were summed to obtain LDC totals. World wheat prices were estimated also. (Although the analysis is for total cereals, wheat, rice, and feed grains, the price of wheat is used in the computations because it is the major food import.) Estimated coefficients of the model were generated from 1960-75 data. Then 300 simulations were run for each of five years (1978-82).

The insurance scheme was designed to stabilize consumption and stabilize grain import costs for LDCs. It presumes food import costs are the best measure of food security in LDCs. An insurance scheme could operate as an international financing program or a combination financing and grain reserve program. An international body was presumed to provide LDCs with *money* to partially pay for grain imports when high world prices pushed up grain import bills (called compensatory financing) or with *grain* when domestic production fell short. The expected food import bill would trigger the program. The scheme did not seek to replace 100 percent of grain shortfalls or of excess import costs.

Operating costs of a five-year program were estimated with no grain reserves and with five different sizes of reserves. There is a 70 percent chance of the plan costing less than $5.1 billion. Total costs differ little with the various levels of reserves. The savings from smaller reserves are offset by larger compensatory financing payments. Thus the choice between grain reserves and compensatory financing in an insurance program must be made on other grounds. The authors suggest that cost variability is one such appropriate factor. Large reserves reduce variability by reducing the likelihood of extremely high compensatory payments. Another factor is food security, *i.e.*, grain availability. Large reserves increase the probability that LDCs can obtain grain when needed to keep supplies from falling below 95 percent of their trend production. A 20-million-ton reserve is recommended to be combined with a compensatory financing program.

A graph shows tradeoffs between costs and food security for six versions of the insurance program. The versions are six degrees of guarantee offered to LDCs and whether the scheme is a compensatory financing mechanism only or whether it also involves grain reserves. The values of expected withdrawals from the five-year insurance program for 65 LDCs are also given. About 50 percent of costs derive from six or seven countries; India accounts for 20 percent.

The study examines results with various assumed costs of a grain reserve and with various levels of guarantee to LDCs. Compared to the base situation, results are as expected: (1) higher carrying costs for stocks raise the present value of total costs; (2) a higher assumed discount rate reduces the present value; and (3) lower guarantees reduce costs.

Koo, Boggess and Heady [39]

Econometric and simulation models were combined to estimate optimum grain reserve levels. These 1978 models from Iowa State University also focused on weather-induced yield variations and impacts of environmental policies on yields in the U.S. Some options varied export levels, too. Deviations from trend yield during 1921-74 were presumed to measure weather effects. Environmental policies affect fertilizer and insecticide use, soil erosion, and livestock waste disposal. It is argued that controlling these environmental factors increases production variability because they alter traditional regional production patterns, making production more susceptible to the vagaries of weather. Reserves were considered a means of mitigating fluctuations in supplies caused by the weather.

Estimates were made for reserves of U.S. produced food grains, feed grains, and total grains. (Food grains include wheat, rice, rye, and soybeans. Feed grains include corn, barley, oats, and sorghum.) The analysis covered three levels of protection for each of three assumed weather conditions. Protection was for: (1) 90 percent of domestic shortfalls and 60 percent of foreign shortfalls; (2) 90 percent of domestic and 75 percent of foreign; and (3) 90 percent of domestic and 60 percent of foreign assuming that domestic and foreign shortfalls occur the same year. The weather conditions were the worst expected for 10, 20, and 40-year periods. Foreign production shortfalls were estimated for 11 major producing and consuming regions in the world, based on 1952-71 data. It was assumed that a maximum of one-half of available U.S. reserves could be released for use in any one year.

The level of reserves needed was found to depend on the size of the expected shortfall and on how much of a maximum expected shortfall would be covered by stored grain. Estimated reserve levels for all grains studied range from 14 to 30 percent of U.S. production. In 1985, U.S. production of all grains is estimated at 296 million metric tons so stocks would be 41 to 89 million metric tons.

The size of expected shortfalls increased as the planning period lengthened (*i.e.*, the maximum shortfall is greater for a 40-year period than for a 20-year period, and both are greater than for a 10-year period). However, the probability of a given maximum shortfall occurring in a given year falls as its size increases. Per unit, as well as total, costs of reserves increase as stock levels are raised because grain is held longer on the average to protect against rare events.

Policies that raise production levels, such as policies to expand exports, or that impose stringent environmental controls on producers tend to increase production variability. Hence, larger stocks are required to achieve protection against shortages than in the absence of such policies.

Grennes, et al. [37]

A world wheat trade model is used to compare reserve stocks with reductions in existing trade barriers as a means of stabilizing prices. Policies of major trading nations in the early 1970s are examined in this North Carolina State University study. In 1973/74 Canada, Australia, Argentina, and the European community insulated their domestic markets from the high world prices then prevailing. This analysis showed that release of 7 million tons of stocks would have prevented the U.S. price from rising. If insulating policies had not been followed, only 4 million tons would have been adequate. The authors conclude that substantially larger stocks are required to stabilize prices in the presence of trade barriers than are needed when trading nations share market fluctuations.

Konandreas and Schmitz [38]

This 1978 study from the University of California (Berkeley) tested empirically the theoretical finding that benefits of price stabilization, in an international trade context, occur for the country causing instability. In reality, however, destabilizing influences usually cannot be traced solely to one nation. Hence, to decide whether stabilization policy is good or bad for an individual nation, an empirical test is necessary. Such a test was the object of this research. It examined the desirability of grain price stabilization for the U.S.

The measure of desirability employed is the sum of producer and consumer welfare gains. For stabilization to be desirable, the sum must be positive. If the result is negative, there is a net loss and stabilization is undesirable on economic grounds. Costs of storage to stabilize prices are excluded from this analysis.

Linear economic models of wheat, corn, sorghum, barley, and oats markets were estimated from data for 1955-72 for the U.S. and the rest of the world. Estimates of expected values and variances of prices are obtained from the model for further analysis. The price variance is divided into two portions, that due to domestic production fluctuations and that due to foreign production variations. The latter is taken to represent fluctuation in foreign export demand for U.S. grains. From these, expected consumer and producer gains are calculated.

Results indicate that the U.S. benefits from price stabilization for each of the four feed grains. Results for wheat are inconclusive. However, if storage costs are added, a policy to stabilize U.S. wheat prices could not be economically justified. Most price instability for feed grains comes from inside the U.S. and for wheat it comes from foreign demand.

Separate calculations related dependence of each grain on exports (the share of U.S. production exported) to the source of instability (whether domestic or foreign). In general, the greater the dependence on exports, the more instability comes from foreign sources. The findings of this research support the general theoretical conclusion that instability benefits exporters while importers benefit from stability.

O'Carroll and Traylor [41] (rice reserve)

An econometric model of the U.S. rice market was estimated in 1977 at Louisiana State University, and the results were used in a simulation model to evaluate reserve stock options. Demand and supply relationships for the econometric model were estimated with 1955-75 data. The simulation model generated means and measures of variability from 500 runs for each of six years (1975-80). Yield and export equations contained random terms to represent unpredictable annual influences. (These simulation experiments for rice draw upon and closely resemble Sharples and Walker's work on wheat and feed grains.)

Several government storage programs were compared with one another and to a no-program situation. None of the alternatives allowed for private storage or for government production controls. All reserve stock options employed price-band triggers. Three bands, of different widths, were centered on the mean price generated by the no-program model, one centered below and another above that mean. The effects of three different levels of beginning stocks also were examined. The criteria for evaluating the various options are level and dispersion of prices, production, domestic consumption, exports, farm income, size of buffer stocks (including the likelihood of zero stocks), and costs of the storage operation.

All reserve stock options reduce the price and income variation below that of the no-program situation but increase the variation of acres planted and production. There is little difference in the level and variation of domestic consumption and exports, except that export variation increases as the size of beginning stocks increases. There is great variation in rice stock sizes from year to year, thus annual costs vary greatly in this model. Average stocks ranged from 10 to 20 million hundredweight (approximately 0.45 to 0.90 million metric tons).

Widening the price band reduces stocking activity, the average level of stocks (thus costs), and the chance of zero stocks while raising the variation in stock sizes. Greater variation also occurred in estimated prices and farm income as the band is widened. Moving the center of the band from below to above the mean raised the levels of prices and incomes but increased their variances. Stocks and costs were larger but less variable. The chance of no stocks being available was reduced.

When the size of initial stocks is increased, higher average prices occurred, and the chance of having no stocks rose. Average annual costs were lower.

The stock program with the price band centered above the mean provided the best results for stabilizing the U.S. rice market and for assuring supplies when crops are short.

Chaipravat [33] (rice reserve)

A world buffer stock program for rice is analyzed with a simulation model, using estimated production, demand, and price relationships generated by an econometric model of rice markets in 83 countries. This research was done in the Bank of Thailand. The study period was 1960-76 for the historical analysis and 1977-96 for the simulations.

The simulation model estimates world demand, output, and prices. To estimate future fluctuations in world output, deviations from trend were calculated from 1956-75 data. These deviations were entered in simulations as stochastic shocks in two ways: (1) randomly selected for each of the 20 years, and (2) chronologically, presuming a repetition of the previous 20-year weather pattern. Results from these two experiments were compared with a third experiment in which prices and output were estimated without stochastic terms. Expected values from the first experiment were obtained from 30 runs. The values were very close to those generated by the third experiment without stochastic terms.

The hypothetical buffer stock authority bought and sold rice to keep prices within a specified range of "normal" prices. Ranges of ± 5 percent and ± 7 percent were evaluated. Also evaluated were: (1) the minimum size of beginning stocks needed to prevent running out of rice during the 20-year study period; (2) maximum credit needed to finance the operation; and (3) profit or loss resulting from the program. Results based on 5 percent and 7.5 percent interest rates were compared.

The size of initial rice stocks is directly related to the assurance of having adequate stocks. Large beginning stocks are needed to meet price targets if a high degree of confidence is desired. Large stocks require a large financial commitment. A small financial commitment permits only a small stock and introduces more risk of exceeding price goals.

Financial resources are also needed to support prices. A high maximum credit line is required to assure a high degree of confidence in having enough money to purchase rice when prices are low. To achieve a 70 percent probability of success for the 20-year program, $10 to $40 billion must be committed. For comparison, the 1976 value of world trade in rice was $2.5 billion.

If credit is available at a 7.5 percent interest rate (or higher), the buffer stock is apt to be unprofitable. However, it would be profitable at a 5 percent rate. The test of price band width showed that costs are greater with the narrower price band, as would be expected.

6. Optimal Programs and Storage Rule Analyses

Gustafson, Gislason, Johnson (University of Chicago) [11][12][13][14]

Several researchers associated at one time or another with the University of Chicago have utilized the optimal carryover approach, estimated mainly with dynamic programming techniques, to investigate grain storage issues. The optimal approach generates storage rules that will maximize expected welfare (benefits or gains to the economy) from a storage operation. Only those benefits and costs reflected in demand and supply curves enter into the analyses. Nonmarket externalities are not formally incorporated into the model. Optimal stock sizes calculated by this model generally are in addition to commercial working stocks; they are held in anticipation of future profits. These are inventories which a profit-maximizing private storer would hold in a perfectly competitive market.

Two early studies by Gustafson [11] and Gislason [12] focused on the U.S. grain market. Gustafson, in 1958, showed that private storers would carry out optimal storage activity under free competition They would store and release grain so that expected marginal return from storage would equal marginal cost. The storage decision requires knowledge or estimates of storage costs together with estimates of the level and variability of current and future supply and demand. Expected future costs and benefits are calculated in terms of present value.

Gislason investigated two models in 1960. One assumes storage decisions are made for one period at a time, when carry-in supplies and new production are known. It represents speculators' behavior. The other reflects a public storage program designed to maximize returns to the storage agency. It is called an "ever-normal granary" model. The analysis is for an unlimited time horizon.

Both Gustafson and Gislason tested their models with data before 1950, hence the empirical findings have little relevance now. Their contributions are mainly methodological and serve as the foundation for more recent research.

Analyses by Johnson and others in 1976 and 1978 applied the optimal method in evaluating desirable grain stock levels for the U.S., all of North America, other countries and regions, and the world [13][14].[2] The authors argue that grain reserves are desirable chiefly because there is not free trade in grains. Worldwide production fluctuations are small in percentage terms. So if grain were marketed freely among nations without restrictions, there would be little need for storage other than working stocks.

In each successive study the computational procedures have been improved to make the model increasingly realistic. However, the need for further improvements is recognized. Necessary restrictions on the mathematical form of demand and supply functions crucially influence the empirical results which are obtained. In addition, the authors argue that disaggregation of the grains is needed to reflect substitution effects accurately. Many current studies imply perfect substitution among all grains — a possibly misleading supposition.

Optimal stock sizes are evaluated at several probability levels. The interpretation is that the estimated optimal stock size would not exceed the amount specified at a particular probability level. For example, the 95 percent probability level means that there is only one chance in 20 that the optimal stock size generated by the model would be greater than the specified amount.

Comparisons of optimal stock size among nations show that stocks as percentages of production vary greatly from one nation to the next. The differences stem from differences in the estimated variability of production and demand. The more net variation there is, the larger the optimal stock. Estimates for the U.S., for example, indicate that about one-half of national stocks are required because of export demand variability.

[2] Also see the discussion of Hillman *et al.* [3].

The impact of trade policies is analyzed also. Trade clearly reduces optimal stock sizes. In one example, optimal stocks of all grains within the Far East region for a given year would be 7.5 million metric tons, assuming free trade within the region. This compares with 22.5 million tons with no intraregional trade and each nation stocking for its own contingencies. Therefore, the authors conclude, stock policies depend importantly upon both trade policies and the physical ability to trade (*i.e.* access to transportation and marketing facilities). Thus, useful estimates of regional or global stock requirements must consider actual or expected trade restrictions of many kinds.

The analyses show that desirable stock levels are sensitive to the response of demand to price. Hence, good estimates of demand elasticities are needed to evaluate benefits and costs of stock programs accurately.

Tests with various cost assumptions illustrate that optimal stock levels decline as costs rise. The impact of costs on desirable stock levels is less at a 95 percent (or higher) probability level than at lower probability levels. In other words, per unit increases in storage costs have less impact on optimal stock sizes when the storage policy runs little risk than when more risk is accepted. Similar conclusions emerge when the impact of the future price level is considered. A downward trend in grain prices reduces future benefits of today's grain stocks. Desired stock levels are therefore lower than if prices tend to remain constant or rise.

Separate analyses were made of an international insurance scheme designed to meet extreme production shortfalls in the LDCs. Shortfalls equal to or greater than 4 percent, 5 percent, or 6 percent below trend production were considered extreme. An insurance program to make up LDCs' production shortfalls of 6 percent or more from 1955 to 1973 would have made annual grain payments of 0.1 to 14.8 million tons, averaging 4 million tons. Insurance for extreme situations reduces national storage needs for LDCs substantially. If there were an international insurance program to meet shortfalls of 6 percent or more, India's annual domestic stock needs drop from 13.5 to 7.5 million tons and Thailand's from 6.2 to 2.1 million tons, for instance.

Hillman, et al. [3]

The economic advantages and disadvantages of reserve stocks in a world context are spelled out in this 1975 paper written for FAO. Besides delineating political and economic issues surrounding grain reserves and offering some policy recommendations, two separate analytical exercises are reported and discussed. The first concerns stocks to stabilize grain markets. (The authors call these "stocks for commercial contingencies.") The second analyzes reserve stock needs to meet periodic emergency situations in LDCs.

The discussion of stocks to mitigate extraordinary price gyrations in commercial markets is developed mainly with logical arguments and illustrative data. The authors cover: (1) the merits of nationally and internationally-managed schemes — they prefer the latter on cost grounds but recognize that political realities may preclude a completely international scheme; (2) location of stocks — they point out the economic advantages of stock holding in exporting countries and the disadvantage that such stocks are not near the likely locations of grain shortages; (3) costs and cost sharing — they support cost sharing based on consumption since consumers benefit most from reserve stocks; (4) stock size and stocking rules — they argue that price rules with a rather wide band are preferred to quantity rules and suggest that a 30-million-metric-ton reserve may be feasible but more analysis is required to make sound decisions.

A fairly simple calculation of the marginal value of corn when prices were low (1970) and when they were high (1974) suggests much more inelasticity in demand at higher prices than at lower prices. Because demand elasticity values are crucial to the evaluation of benefits and costs to consumers and producers (and to importing and exporting nations), the authors make a strong argument for more refined and more reliable estimates of demand elasticities.

A more sophisticated analysis was made of optimal stock levels for four LDCs (India, Indonesia, Philippines, and Pakistan-Bangladesh) and four regions (Africa, the Near East, Latin America, and "other" Far East — excluding communist nations and the four countries analyzed separately). The research, conducted at the University of Chicago, followed the optimal inventory procedures discussed previously. Three alternative stocking programs were examined: (1) each of the eight countries or regions holds reserves for its own use; (2) a supra-national agency holds reserves to meet needs of the LDCs analyzed; and (3) an insurance scheme. Under the insurance scheme, an international reserve would supply grain when national shortfalls equaled or exceeded 6 percent of production. National storage programs would be operated to meet less extreme circumstances.

Under the first program the sum of optimal stock levels for the eight individual countries or regions was found to average 13 million metric tons. If stocks were held multi-nationally, as in the second program, the average was 7 to 9 million tons. Under the insurance scheme, optimal national or regional stocks were calculated to be about 6 million tons. An additional 3 to 4 million tons, held in the insurance reserve, would be required for extreme production shortfalls. The analysts comment that the insurance reserve could be a financial commitment instead of a physical stock of grain *if* a stock program to meet commercial market fluctuations existed.

Arzac [31]

This 1977 research done at Columbia University features a small estimated econometric model of the U.S. wheat and feed grain markets. The estimates were used to test the markets for cyclical behavior and to analyze stabilization policies. Analytical techniques included stochastic control and dynamic analysis. Estimates were generated from 1947-73 data. The model reveals cycles of about three years in length for quantities demanded and supplied, levels of commercial stocks, and prices.

The policy analysis evaluates several stabilization programs in terms of two welfare criteria. One measures aggregate U.S. gains as reflected in benefits to U.S. consumers plus export revenue minus costs to U.S. producers and storage costs. The other criterion is the "success" of the programs as measured by the gap between policy goals and achievements — the smaller the gap, the more successful the program. Also examined were effects of stabilization on other policy goals. Those goals included maintaining farm income and preventing excessive stock buildup. The time horizon for calculating the welfare measures was ten years.

One step of the analysis compares total U.S. welfare derived from optimal government storage with welfare generated under private storage with no government stock program. Expected total welfare is nearly identical under the two systems. Overall, the results did not change much when a 20-year horizon was tested, when storage costs were raised and lowered by factors of ten, or when the feed grain supply response to price was tripled. These results imply that the policy goals of price stability and maintaining farm income can be pursued without major aggregate welfare costs. However, important distributional effects were observed. Under the government storage regime, wheat inventories and prices were higher. This lowered domestic consumption while raising export revenue. Exports were not assumed to be responsive to price in this model.

The second step in the policy analysis compared performance of a free market with eight packages of government programs as a means of achieving price stability, maintaining farm income, and preventing excessive stock accumulations. Four of the government programs involve storage management, three combine storage and supply management, and the last is a continuation of historical practices. Price levels for 1972 served as the benchmark.

With no government programs (the free market alternative), prices declined more from their 1972 levels than under any of the other policy options examined. Also, price variances are greater under a free market system, with one exception. Prices varied more under a continuation of historical programs than with the free market case.

The four storage-management programs differ according to the relative importance assigned to maintaining price levels and to preventing excessive stocks. The results show the potential trade-offs between stock sizes and price levels. To keep prices at or near 1972 levels, large government stocks accumulate. Estimates of average government stocks ranged from 20 to 85 million metric tons. If smaller stocks are desired, lower price levels must be accepted. All storage-management programs resulted in higher and less variable prices than did the free market alternative. None of these four programs reduces total U.S. welfare below that of the free market case. However, farm revenue grows faster under the free market than with the programs.

Two of the programs which combine storage and supply management do not allow for changing the storage and supply targets within a given year; the third does. Supplies were managed in the model by adjusting levels of concessional exports of grain. It was assumed that removing surplus production from the market by concessional exports had the same impact as curtailing production. All three storage and supply-management programs did maintain price levels and avoided large stock accumulations, as anticipated. Under these regimes, the average level of government stocks was between 5 and 8 million metric tons.

The results show that there is a trade-off between variances in stock levels and concessional exports — to reduce large fluctuations in one, large fluctuations in the other must be allowed. Under the program that allowed intrayear government stock and export adjustments, smaller price variances, but larger variances of stock sizes and concessional exports, occurred.

If past policies were continued, prices would rise without accumulation of stocks or without increases in concessional exports. The cause was reduced supplies. Variances of prices and stock sizes were sizeable. In fact, prices were more unstable than under any of the other eight cases. This implies that more stable prices could be obtained if stock management is added to past programs. The author concludes that his research shows that total national welfare is affected very little by a wide range of grain market-management policies.

Talpaz and Taylor [42]

This 1977 study applies the "certainty equivalence" method to analyze reserve-stock/price-stabilization issues. The authors argue that this general method of optimal analysis is superior to others for estimating desired stock levels because it permits disregarding future uncertainty when making current decisions.

Optimum stock levels determined by the certainty equivalence method are compared to those generated by the current system (*i.e.*, a continuation of historical practices) and by a system which assumes perfect knowledge of the future. Although the last is unrealistic, it provides a "best solution" benchmark for comparison.

These analyses were based on an econometric model of the U.S. wheat economy, estimated from 1960-74 data. The model included behavioral equations for U.S. acreage planted, yield, demand (domestic food, feed, seed, and export), stocks, and rest-of-world wheat production. Results of the stock optimization problem were simulated for five years (1976/77-1980/81) with 50 replications for each year. A moving seven-year time horizon was used. Sensitivity analysis revealed that a longer horizon did not change the current decision appreciably. Results are given under low and high levels of exports, representing pre and post-1972 export conditions, respectively.

The comparison between the current system and the certainty-equivalence optimal rule did not produce a clear-cut winner. Although the latter rule gave results for stock levels and welfare closer to the perfect knowledge case, it generated more price variance. Prices were especially variable in the first year or two after a sharp shift in export demand, such as occurred in 1972. Under the current system, stocks were estimated to build up to 27 million metric tons in 1980/81 if high exports continued, substantially higher than under the optimal rule tested. Because of its disadvantages, the authors suggest that the certainty equivalence approach is a better analytical research tool than an operational guideline.

In a separate exercise, the sensitivity of the model was tested with various weights assigned to domestic and foreign consumer welfare. The rationale for unequal weighting is that an exporting nation may value its own consumer welfare more than that in importing nations. Substantial differences in U.S. stock requirements resulted from such weighting, and those differences created large price impacts. Thus, the assumptions made about domestic and foreign welfare seriously affect research conclusions and the policy positions recommended for exporting nations.

Gardner [36]

This paper from Texas A&M University develops the optimal inventory approach to grain storage, incorporating previously unaccounted for (or inadequately accounted for) aspects related to stocking activity. First, a hypothetical example is developed, then storage rules for a world wheat stock are determined, and lastly the approach is applied to the U.S. wheat market, with data representative of 1977/78 conditions. The analytical approach builds on the University of Chicago studies discussed earlier.

New features incorporated in this study are: (1) supply response to price; (2) interaction between public and private storage; (3) cyclical behavior in yields (a series of good crops followed by a series of poor crops — most studies assume random annual yields); and (4) costs of nonmarket externalities when there are grain shortages (per unit non-market costs rise as supplies become smaller).

Two optimal storage rules are developed; one includes externalities (called "socially optimal") and the other excludes externalities (called "privately optimal"). These rules are compared to price-band storage rules for public storage programs (called buffer stocks), and to a public subsidy for private storage, with and without an accompanying buffer stock program. Comparisons are then made on price variance, likelihood of extremely high or low prices, mean level of public and private stocks, public storage costs, and welfare effects.

World market. For the world wheat model, the welfare measure is the present and expected value of wheat consumed, less production costs and costs associated with externalities.

The author first evaluated three optimal storage rules: one without production response to price and without externalities (base case); one with externalities; and the third with both externalities and production response. Then mean stock sizes and price variations under the second of these regimes were compared to results generated under several buffer stock schemes. Results are based on 500 simulations.

Optimal storage when externalities are included (the second case), when compared to the base case, shows larger mean stock levels (30 as compared with 9 million metric tons) and less price variation (standard deviations of 54 cents and 87 cents per bushel, respectively). If production adjustment is allowed in the analysis (the third case), price variation is further reduced (to 40 cents), but average stock levels are higher (44 million tons). The latter occurs because larger stocks are needed to assure supplies when crops are short since less is carried over from previous production which, in turn, falls when prices are low.

The buffer stock plan considered most realistic by the author would acquire and dispose of stocks when prices were 10 percent below and 40 percent above the mean level, respectively. Consequently, there would be ample incentive for private storage in the price range where no buffer stocking activity occurs. The scheme's price range is centered above the mean because it is at above-mean prices that the non-market externalities become important and private storage becomes sub-optimal. Then buffer stocks can play an optimizing role. This stockpile would have a 30-million-metric-ton ceiling. Under such a program, mean buffer stocks are 26 million metric tons, mean private stocks are 7 million metric tons, and the standard deviation of price is 61 cents per bushel.

A program offering a subsidy to private storage yields a mean stock level of 26 million tons and a 56-cent standard deviation. This program most closely resembles the socially optimal solution. It is therefore the author's preferred option in the world context.

These results assume that the future trend of price is known. But that trend can be uncertain. If that uncertainty is taken into account, optimal storage levels would be greater than those reported.

The author states that optimal storage rules could be triggered by prices or quantities, and he argues that price indicators are subject to more error than quantity indicators because there is greater uncertainty of future price trends. Nonetheless, price may be more feasible to use in a national context because of the unpredictability of foreign demand. The problems associated with price triggers can be mitigated if flexibility is allowed in setting and changing acquisition and release prices.

U.S. market. The analysis of wheat storage for the U.S. is more elaborate than the world model. It involves two factors not relevant in the world case, variability of export demand and the exclusion of consumer benefits in importing nations from calculations of welfare. Also, the physical costs of storing wheat are specified differently. A lower cost is applied to the first 5.4 million tons above working stocks (9.5 million tons) because that quantity is assumed to provide convenience to holders. And, as was true with the world model, per bushel physical costs are increased as stocks approach capacity. Interest rates are a constant per bushel charge at all stock levels.

Results from the privately and socially-optimal storage rules and from seven buffer stock and/or storage-subsidy programs are generated from 800 simulation runs. Optimal and buffer stock plans give much the same pattern of results on stabilization and cost measures as the world case, except that the storage subsidy program does not come close to the socially optimal results for the U.S. Adding a small buffer stock (6.5 million ton maximum operated with price triggers of 80 percent and 160 percent of the mean price level) to the subsidy program improves stabilizing performance, but at a high cost. None of the various buffer stock schemes tested came close to the socially-optimal rule on welfare criteria. The author states, however, that further testing of price bands and maximum sizes might find a "better" buffer stock plan.

The following direction of consequences can be expected: (1) lowering the acquisition price reduces the mean stock size and leads to lower costs, but it also lowers chances of reaching the maximum stock level thus providing less ability to meet extreme shortfalls; (2) lowering the release price reduces the length of time stocks are held (lowers costs) and increases the chances of having no stocks for shortfalls; (3) widening the price band increases price variability and lowers mean stock levels and costs. It is also shown that a non-symmetric price band, centered above the mean, gives results closest to the socially-optimal rule. This happens because of the combined effects of public and private stocks on welfare and stability.

7. The State of Knowledge: Summary

Research on grain reserves is diverse in objectives, methods, and assumptions. The studies produce few common threads and few broad-based lines of agreement. Yet, many are comprehensive in scope, sophisticated in method, and ingenious in execution. They are serious in the intent to provide useful answers to difficult questions about grain reserves in an uncertain world. Because of the diversity among studies, no single "best" policy for a national or international storage program emerges. Yet much has been learned to clarify questions about grain reserves and narrow the range of reasonable answers.

A synthesis of what we know about the types and operations of grain reserves and their impacts on markets is the focus of this section. First is an introduction to provide a framework for considering grain reserve research. It defines terms, clarifies points and delineates guideposts for making comparisons among the studies. Next are findings which are consistent across studies. In the last part are findings which are for studies of a particular focus.

Overview

Goals of Grain Reserve Policies

The research discussed in this report deals with two interrelated policy goals: market stability and food security. Both are sought in order to mitigate adverse consequences of grain supply fluctuations (caused mainly by weather fluctuations) and magnified by trade barriers. In both categories several hypothetical types of reserve programs have been researched: reserves held by an international agency, by individual nations for their own consumption, by exporting nations, and by groups of nations.

Studies emphasizing market stabilization for the world or an individual nation view grain storage programs as one means to that end. Many do not address impacts of instability and storage on vulnerable groups in the world's population. Some argue that shaving the peaks and troughs from price fluctuations contributes indirectly to food security.

Studies on means to prevent critical food shortages usually stress supply-availability for poor nations and for poor people in those nations. The impact of storage on prices is often secondary.

Food aid is clearly related to food security. History reveals that donor nations' contributions rise and fall as their supplies rise and fall. Food aid linked to supply, not need, may endanger rather than promote food security in developing countries. It is widely agreed that a storage program to stabilize prices and/or supplies would reduce the financial and political problems of maintaining financial or physical food aid commitments. Although no study reviewed here concentrates solely on food aid, many address the issue.

In general, research sponsored by international organizations (*e.g.*, World Bank, FAO, IFPRI) focuses mainly on grain reserves as a means to assure global or LDC food security while much of the research undertaken by university economists emphasizes national or international price stabilization. These emphases reflect the predominant professional and institutional interests of each group. Research conducted by the

U.S. government falls into both categories, as expected, since both domestic and international policy goals are at stake.

The dichotomy drawn here between market stabilization and food security studies accentuates the two policy goals advanced by one policy instrument — reserve grain stocks. This dual role confounds the debate about grain reserve policies. Those most concerned with food security may not pursue the implications of their proposals on grain markets. Conversely, those emphasizing price stabilization may not thoroughly examine food security implications. While many research findings in this field are complementary, others appear contradictory. Hence, it is a good idea for anyone trying to use this research to identify the policy perspective of the writers.

What Constitutes the Stock?

Fundamental to any discussion of grain reserves is a clear understanding of what constitutes grain stocks. The broadest category is total carryover from one harvest to the next. Carryover includes minimum working stocks (also called pipeline supplies); additional working stocks held by consumers or merchandisers to meet future needs; speculative stocks, held in anticipation of future profit; and stocks segregated from normal market channels to meet special needs. The last category includes non-market stocks — those accumulated to stabilize or support prices, to fulfill food aid program commitments, and to meet unanticipated emergency food needs when disasters strike (*e.g.*, floods, droughts, war). Grain reserve proposals embrace all of these. Consequently, many different stock size targets can be consistent with one another insofar as they are designed to cover different portions of carryover requirements.

There is some consensus that global stocks were drawn down to pipeline levels in 1973/74. As percentages of consumption, these levels were: 17 percent for wheat, 10 percent for rice, 11 percent for coarse grains, or 12 percent for all cereals. On this basis and at a consumption level of 1,400 million tons in the late 1970s, working stocks of all cereals would be about 168 million tons. Average carryovers were actually 189 million tons, indicating world reserves (in some sense) were about 20 million tons.

Studies consistently refer to interyear stocks. None examine intra-year storage activity. However, they differ with respect to what stock size target is estimated or recommended. Some indicate an average size over time; others refer to a maximum or capacity level. A reserve stock to *average*, say, 20 million metric tons, would require a substantially greater storage and handling capacity. Obviously, to make accurate comparisons among studies the same definitions must apply.

The Grain Composition

The grain or grains included is another issue. Substitution between grains in consumption is assumed or implicit in each study. It ranges from perfect substitution in studies of total grains to no substitution when only one grain is studied. In the U.S., wheat and rice are principally food grains while most corn (maize), barley, oats, and grain sorghum are fed to animals. In other nations, feeding of wheat is more common and food uses of the "feed" grains are prevalent. The question of substitution is important because more consumption adjustment is feasible in animal feeding than in human feeding. When feed prices are low relative to livestock prices, herds are increased, and feeding ratios per animal are increased. The opposite occurs when feed prices soar.

Substitution is especially important in estimating expected production shortfalls and stock size requirements to offset those shortfalls. Substitution among grains is recognized by many analysts, but it has been inadequately incorporated in studies to date.

Protection Level

How much stability and protection against food shortages "should" be provided is a matter of judgment and is directly related to stock-size decisions. Such judgments reflect researchers' values and influence the designs of their studies and the conclusions they draw. Besides these subjective aspects, stock size and level of protection conclusions will depend on research assumptions concerning: (1) the occasion of poor harvests (that is, are poor harvests purely random events, do they occur cyclically, or what?); (2) the behavior of governments and the structure of grain markets; and (3) the time horizon of the particular study. Diverse conclusions may be reached if a stock program presumes a short life (perhaps 5 years) or a 20-year or longer undertaking. Calculations of costs and benefits are especially sensitive to the time dimension. The longer the time horizon the greater likelihood there is of a very large shortfall. Thus benefits from storage increase, but so do costs because grain is held longer.

Public Versus Private Stocks

The relationship between publicly and privately held stocks is disregarded or is ambiguous in many studies. Most presume that a national or international program is operated by an agency subject to governmental direction. Storage schemes operated according to prescribed rules presume such a management system whether or not it is made explicit. Profitable government storage probably replaces private storage ton for ton. Unprofitable government storage is likely to replace private storage on a less than one-to-one basis. Empirical evidence on substitution rates is not definitive. A public subsidy to private storage tends to increase storage levels without shifting stocking activity from private to public facilities. But subsidized private storage and publicly-owned storage will not operate identically because decision criteria differ.

A public storage program employing a banded rule of some kind allows for private speculative storage within the band. Analyses which ignore the stabilizing effects of such private storage overstate the benefits of a public storage program. (For instance, one study estimated that moving from a no-storage regime to one with *only* private storage reduced price variation by two-thirds, as measured by the standard deviation of price.)

Operating Conditions

All of the studies used annual data (totals or averages) in the calculation of estimates and in the analysis of reserve operations. Results are typically reported in terms of annual levels of stocking activities and annual average prices. Any actual stocking or reserve program will have to operate on a day-to-day or month-to-month basis. Hence, the existing studies will provide only limited operational guidelines.

Some General Findings

Much of the debate about grain reserves centers on stock size and operating rules. These issues are addressed in nearly all of the studies examined. This section contains some findings confirmed by several studies, though one soon learns that answers to these seemingly simple questions are not simple. Also widely debated is how benefits and costs are distributed among economic groups in a country and between countries. There are no unqualified answers to these welfare questions. Underlying all of these issues are questions about the correct demand, supply, and trade relations to be used.

Demand and Supply Functions

Most of the studies reviewed either estimated or assumed appropriate demand, supply, and trade relationships for grains. The nature of these functions is crucial to the conclusions.

Supply curve shifts (production variation). Since all grain storage proposals seek to smooth out supplies between years of plenty and years of scarcity, the amount that supply curves shift from one year to the next is a fundamental concern. The more variation there is, the more benefits accrue from storage, so larger stocks become desirable.

For the world as a whole, grain production does not vary much from year to year — a maximum of perhaps 3 or 4 percent from trend. This suggests that relatively small stocks in combination with modest consumption curtailment could adequately offset world production shortfalls. Such is not the case, however. Only if grain could move freely from regions of abundance to regions of scarcity and if grains substituted perfectly for one another, would variation in global production of all grains be an appropriate measure.

In the absence of free trade, national production variation becomes relevant. Moving from the global to the national level has dramatic implications for stock requirements. If nations adopt policies to balance interyear supplies with internal stocks and no trade adjustment, total world stock requirements soar. On the other hand, if trading nations seal off their domestic markets from international market fluctuations, they transfer the impact of all production variation to world markets. Under free trade, international market fluctuations would reflect into national markets, encouraging some domestic consumption and production adjustment as well as adjustment in trade flows. When major trading nations insulate their domestic markets, as is the case in today's world, nations without compensating trade barriers become the shock absorbers.

Since national situations and policies differ greatly, reserve grain stock considerations for national purposes must be analyzed separately. Conclusions for one nation most likely are inappropriate for another.

Elasticities. The price elasticities of supply and demand functions also have substantial effects on the calculation of desired stock sizes as well as costs and benefits to economic groups. Although it is generally agreed that price inelastic demand and supply curves are appropriate, there is no universal acceptance of the exact elasticity values or equation forms. Yet modest changes in these elasticity values (say from −.1 to −.2 in a demand function) may make substantial differences in conclusions.

As demand elasticity is increased, the need for stocks to stabilize markets diminishes. Benefits of storage to consumers diminish. This occurs because consumers are willing to alter consumption more in response to price. If total supply responds to price, even with a lag, market prices vary less than if there is no supply response. The more that the quantities demanded and supplied adjust to price changes, the less prices vary through time. Therefore, there is less need to intervene in markets to reduce price instability.

In the case of grains, however, response of planted area to price does not always reduce market instability. The unpredictability of yields is the reason. For instance, if producers cut acreage after a year when prices are low, an unanticipated drop in yields will further reduce supply. Hence, supplies may be more unstable and larger stocks may be needed than if acreage does not respond to price.

Policies. National policies affecting supply and demand also influence estimates of stock needs and welfare. If production control policies reduce acreage or marketable supplies when prices fall, they have the same effect as increasing the supply elasticity — the market is stabilized but stock needs may rise.

On the demand side, if low-income consumers are guaranteed minimum levels of grain *via* food aid, storage generates lower benefits for consumers over time. Since a vulnerable group of consumers is already assured of food supplies, there is no additional benefit from storage for them. However, from a government's viewpoint, storage can substitute for or reduce costs of other food aid programs.

Food aid. Some studies add food aid to commercial demand for grains. In a global context, food aid has little impact on results. At a national level, or in analyses focusing on LDCs, food aid demand is important because it changes the shape and elasticity of demand relationships and foreign exchange requirements to import grain. For example, in one global study, food aid demand was assumed to reduce demand elasticity at high prices. As a consequence, greater benefits from storage resulted.

Shape of curves. The shape of demand and supply functions is a further consideration. Linear demand curves are widely employed for computational ease. Yet they imply that demand responds relatively more to proportional price changes at high prices than at low prices, reducing benefits to consumers from storage. Neither logical arguments nor empirical evidence support this behavior. A demand curve with constant elasticity or one that is more inelastic at high prices seems more suitable. Because of the essential nature of food the greater the shortage the more difficult consumption adjustment becomes.

The decisive role of demand and supply relationships and the uncertainty of their accurate representation in grain reserve studies cast doubts on the precision of quantitative results. Qualitative results such as direction of change and some relative magnitudes are less subject to error. Some studies use simulation techniques to test how sensitive results are to changes in underlying parameters or assumptions of the models. When reported, this type of analysis provides useful information for the reader in evaluating the sensitivity of conclusions to elasticity and related estimates.

The Role of Trade

The discussion of world grain production variation suggested that free trade could do much to stabilize grain markets, reducing, if not eliminating, the need for public storage policies. Yet nations persist in seeking a relatively high degree of self-sufficiency even if grain can usually be obtained more cheaply abroad. Others control exports even if selling all of their grain would be very profitable. Because of the essential nature of grain in the food supply of nations, governments are not willing to risk shortages despite high costs of insulating policies.

Some developing countries have additional constraints. Without assistance, it may be impossible for some LDCs to finance commercial imports of grain. The problem is most acute when world prices are high. Because aid programs usually are fixed in monetary terms, they can contribute to the problem. Moreover, many LDCs have inadequate and inefficient distribution systems for handling large volumes of imported grain.

Thus, complete reliance on trade to offset national production variation is not feasible. Storage programs are a substitute. The interaction of trade and storage is illustrated in several studies. One estimate of the impact of trade barriers in 1973/74 demonstrates that the rise in U.S. wheat prices could have been prevented by release of 7 million tons of stocks *or* 4 million tons if trade controls in major trading nations were simultaneously abandoned.

Rules for Stock Acquisition and Disposal

A variety of storage rules have been examined in the empirical research. Some studies specify stocking activity linked to prices, others to quantities, and still others combine price and quantity rules. Analysts emphasizing price stabilization tend to explore price rules most extensively and those concentrating on food security tend toward quantity rules.

Most of the reserve programs operate actively only when prices or quantities move outside a specified band. "Optimal" programs are an exception. They hold the possibility of continual activity. One analysis combined a banded price rule for a public storage program with optimal private storage activity occurring within the price band.

Some analysts conclude that a price rule is best for a national public storage program. They argue that optimal and banded rules, triggered by quantities, require production and inventory information that cannot be obtained easily and in time for appropriate stocking action to be taken.

On the other hand, price rules can create trouble if their level cannot be adjusted to account for long-run price trends. If the band is too low, stocks will be depleted frequently. If it is too high, stocks will keep accumulating. Another disadvantage of price rules is that stocking activity may be inadvertently triggered by short-term price movements. When prices are climbing the danger is greatest. Scare buying, unfounded rumors or temporary transportation bottlenecks may push prices above the release level even if unwarranted by fundamental market conditions.

A plausible argument is that a banded rule should be centered above the mean of the price trend. This increases the likelihood that stocks will be available for extreme shortfalls.

Many studies experiment with the width of banded price rules. Widening the price band reduces average stock sizes needed to provide a given level of stability. Thus, costs are less as are chances of having no stocks when major shortfalls occur. With a narrow band, stocks are released even when shortfalls are modest. Prices naturally vary more with a wide band, but the occurrence of extremes is less than with a narrow band which cannot always be defended.

In one experiment, widening a quantity rule led to higher costs. This occurred because the storage capacity was held constant. The wider band, with equal capacity, meant that stocks were held longer, incurring greater storage costs, than when the band was narrower. It did, however, provide more protection in years of extreme shortfalls.

Stock Size and Storage Costs

Storage costs are closely associated with the amount of grain stored. Costs include handling, quality maintenance, and the investment costs of warehouses and the grain stored. The last item reflects the amount of money tied up in storage facilities and stored grain that is not available for other uses. In most situations, costs of storage and stock sizes vary directly and almost proportionately with each other.

There is general agreement that storage will not be financially profitable if stocks are large enough to provide adequate stability and protection to vulnerable consumers — especially poor consumers in poor nations. So financing becomes an issue.

Increasing the size of stocks increases stability and assurance of supplies, but at decreasing rates. Thus, there is a trade-off between stock size, hence cost, and protection. Virtually all the empirical evidence suggests that a grain stockpile to provide full protection against extreme shortfalls in production would have to be unworkably large. However, the size of the needed reserve drops rapidly as the acceptable risk of shortage is slightly increased.

Some studies evaluate alternative levels of initial stock holdings and/or storage capacity. The impacts of initial stock sizes become negligible after the first few years. So, long-term plans can disregard initial conditions. However, these considerations are important when a storage program is set up. Built-in limits on stock accumulation reduce average costs, but also reduce stability and supply assurance. But it is not realistic to presume that any government will allow stocks to accumulate indefinitely.

Stock sizes and storage costs are shown to vary considerably from year to year. This implies that financing arrangements must be flexible.

If a storage program is financed by a government, its operation will affect other related government programs. Costs of programs to protect farmers from low prices and consumers from high prices will be reduced if price extremes are moderated by a storage program. Hence, the net cost of a government storage program may be less than the gross cost.

Future price trends influence the net financial returns of a storage program. An upward trend increases the net and a downward trend reduces the net. Since the future price trend is unknown, it can be treated as uncertain. At least one analyst argues that price uncertainty implies larger stocks.

Some Specific Findings

A number of studies approach grain market stabilization and food security from a global perspective. Another group emphasizes developing countries, and a third takes the view of exporting countries, chiefly the U.S. Within each of these groups a variety of analytical techniques have been used. They can be grouped into three broad categories: (1) time series analysis; (2) econometric and simulation studies; and (3) optimizing methods. Although these are not exclusive categories, one methodology tends to dominate each study.

The analytical techniques influence the scope and focus of the research. Time series analyses permit calculations of trends and deviations from trends for grain production and consumption. From these, estimates can be made of the dimensions of potential problems and the available production capacity to meet current and expected future consumption requirements. Econometric and simulation studies first estimate underlying behavioral relationships in grain markets, then experiment with various storage regimes under simulated future conditions and levels of uncertainty. The effect of unpredictable influences, mainly weather, usually are incorporated. These studies evaluate what success storage programs might have in achieving food security and stabilization goals and how programs are likely to affect producers, consumers, and, perhaps, other economic groups. Optimal analyses focus on designing a storage scheme to minimize costs or maximize benefits for some specific entity like a storage agency, a nation, a group of nations, or the world. The welfare measure preferred by the researcher and the influence of other policies are built into the analysis. This approach contrasts with simulation studies which examine welfare tradeoffs and interactions among policy goals as part of the analysis.

Understandably such differences in perspective and procedures have produced a variety of results. The following sections focus on findings which apply under specific research assumptions.

Global Studies

Those analyzing the world market as a whole usually assume free trade among nations. But, as mentioned, that assumption is unrealistic since much of the instability in grain markets results from trade barriers and related distortions. Estimates of stocks to meet food security or stabilization goals under the free trade assumption are too low when real world trade barriers are considered. However, such estimates are useful as indicators of lower bounds.

Analyses with country or regional components assume free trade within each country or region. Most assume that future international trade will be a continuation of historical trade practices. Some examine the tradeoff between storage and trade as a means of stabilizing markets. The destabilizing effects of trade barriers are clearly shown. It is also shown that a stock to meet worldwide needs, wherever they occur, can be much smaller than the sum of national stocks planned to stabilize each nation's grain supply.

Several studies employed time series methods to analyze production and consumption trends and deviations. These studies are useful for making broad inter-country comparisons of instability, of import needs, and of exporters' ability to meet world demand. Estimates of carryover levels as percentages of production or consumption can indicate year-to-year changes in the world food situation and flag problems warranting more detailed study. These studies show that greater instability leads to greater stock needs. In doing so they give some measure of the relative benefits to nations from a storage program. The data and computational requirements of time series studies are relatively minimal.

These simple methods, however, do not provide feasible guidelines for establishing or managing a national or international storage program. In general, they suggest stock goals or targets that are larger, and thereby more costly, than those generated by more sophisticated analytical procedures.

The more complex studies embody more realistic models of international grain markets and are capable of answering an array of questions. Besides investigating stock sizes and storage rules, many of these studies calculate welfare measures.

They examine benefits (and costs) of storage for producers, consumers, storage agencies, and total economies. In general, welfare calculations are very sensitive to the values assumed or estimated as parameters (elasticities) of supply and demand. Quite different conclusions may be reached when alternative, but equally defensible, assumptions are made.

The usual welfare calculations only measure what the market reflects; hence, goals of storage such as food security to vulnerable groups do not automatically enter those calculations. To account for such costs or benefits, some analysts have adjusted their welfare calculations. These adjustments are useful to indicate the direction of changes in results, but remain highly subjective.

One global study, which assumed more inelastic demand at high prices than at low prices, shows that for the world as a whole, consumers gain and producers lose from storage. Under the assumptions of the studies, exporters lose and importers gain from wheat market stabilization and from stabilization of the total grain market if demand is inelastic. One study of the world feed grain market found that most benefits accrue to the U.S. as the major exporter. The difference in the incidence of benefits occurred because the U.S. is the source of most instability in feed grains markets, whereas it is importers in food grain markets.

Costs and benefits for particular economic groups (*e.g.* consumers or producers) in a nation cannot be identified from a global analysis. For example, a change from one set of stock operation rules to another may increase benefits to the world's producers as a whole, but decrease benefits for producers in a particular nation. Calculations of costs and benefits for an exporting nation differ substantially depending upon what assumptions are made regarding welfare for consumers in importing nations. Most studies with a national perspective disregard foreign benefits and costs. If some allowance is made for such effects, different conclusions can be reached about desired stock sizes.

In sum, grain reserve studies with a global or worldwide scope provide estimates of production shortfalls and market instability which global grain reserves can mitigate. They show how trade barriers magnify the problems caused by production fluctuations and how trade and grain stocks substitute for one another as stabilizers.

Somewhat tenuous welfare analyses indicate that world consumers gain by food grain stabilization while producers lose. Similarly, importers gain and exporters lose. For the world as a whole, storage costs exceed benefits at levels of protection deemed adequate for food security. Because of the sensitivity of the welfare calculations and assumptions of the studies, these are not firm conclusions. Moreover, in most cases welfare effects are calculated without consideration of other policies. For example, if importing countries already stabilize their grain markets with other policies, additional storage may not enhance their benefits. The uncertainty surrounding benefits from storage explains much of the difficulty nations have experienced in reaching any agreement about an international storage program.

Stocks for Developing Countries

The political problems impeding establishment of an international grain reserve led many researchers to explore programs specifically designed to meet needs of LDCs. Since food security is the prime LDC need, policies to stabilize consumption are the focus. The interaction among national programs to aid poor consumers, support farm prices, control trade, and store grain is usually highlighted. For example, consumption can be stabilized by trade at the expense of destabilizing foreign exchange transactions.

Two types of insurance programs have been proposed and analyzed. Both visualize an international agency designed to provide protection to LDCs when conditions are extreme. One plan assumes that grain production shortfalls less than 4, 5, or 6 percent of trend can be met by national or regional stocks. Greater shortfalls would be covered by the insuring agency. This reduces national stock needs markedly. For example, if insurance covers shortfalls greater than 6 percent, there is only one chance in twenty that the optimal stock for India would be greater than 7.5 million tons. Without insurance, the comparable level is 13.5 million tons. For the period 1955-73, this hypothetical insuring agency would have released from 0.1 to 14.8 million tons of grain annually, averaging 4 million tons.

The other plan would be triggered by high food import bills. It emphasizes the financing problem LDCs face when they rely on imports to maintain consumption levels. The international insurer would guarantee financial aid if import bills soared. One particular option combined grain reserves and financial compensation. A high import bill could result from a normal import quantity but high import prices or large import quantities at average prices.

Costs of storage and compensatory payments were shown to offset each other, so neither scheme has a distinct cost advantage. But a grain reserve reduces the likelihood of very high payments which donor nations are likely to find objectionable. Moreover, in years of worldwide shortage, financial assistance to LDCs for maintaining imports would boost grain prices in donor nations, too. For a five-year period a compensatory financing plan with a 20-million-ton cereal reserve would cost $3.7 billion. That plan would guarantee assistance when a nation's grain import bill exceeded 130 percent of trend year after year. Analysis suggests that it would have a 75 percent chance of meeting its objectives.

Grain Exporters

Impacts of storage programs on U.S. and Canadian grain economies were examined in several studies. Since these are major exporting nations, much of the emphasis is on exports. Export variability was found as the cause of most grain market instability in the U.S. This is the consequence of weather-related production fluctuations abroad and stabilization policies of other nations which shift instability to exporters and importing nations without insulating policies. Research shows that reduced variation in exports could reduce instability in U.S. grain markets as much as moderate-sized grain reserves.

Many studies analyze the interactions of storage programs and other government programs for managing supply through acreage controls and noncommercial exports. Effects of various program mixes on farm revenues and incomes, prices, export earnings, and government costs are reported. In general, storage programs are found to be compatible with other programs for managing the level and variation of farm incomes and prices. There are no clear-cut welfare analyses to defend or condemn storage as a stabilizing tool. One study found virtually no difference in total U.S. welfare under a wide variety of domestic farm income-support and storage policies.

There is no consensus regarding how the welfare of foreign consumers should be viewed by exporting nations. Yet this issue is of considerable importance when welfare consequences of stabilization for exporters are assessed. Analyses which ignore these indirect benefits are apt to understate the benefits exporters accrue from a stabilizing grain reserve.

Because large exports and high prices are correlated historically, a stabilizing grain reserve tends to reduce exporters' earnings. However, this result does not consider possible longer-run effects of stability on export earnings. Importing nations may be more willing to rely on trade rather than domestic production if supplies are assured.

Concluding Comments

Although many important economic and political issues are unresolved (and probably unresolvable) by empirical research, the evidence suggests that some reasonable international food security and/or market stabilization goals could be achieved by any of several plausible reserve schemes. Food grain security against most disasters and emergencies could be met by earmarked international reserves of not more than 10 to 15 million metric tons of wheat and rice (mostly wheat) over and above working stocks. Some analysts who would accept a greater risk of episodes of shortage under very severe conditions of production failure see 10 million tons or less as adequate.

If world market prices are allowed to fluctuate freely within bands of ±10 percent to ±30 percent around an agreed level, market stabilization, in addition to food security, could be achieved with controlled stockpiles of wheat and coarse grains in the range of approximately 80 million metric tons down to about 15 million metric tons. The required inventory level within this range depends upon the price band width, the accepted risk of being unable to operate because of inadequate stocks, the price-responsiveness of demand and supply, existing trade barriers, and other factors.

The research reviewed for this report is a very rich source of ideas, approaches, and estimates in the broad field of international food security, grain market stabilization, and inventory analysis. It is no accident that this is so. Competent analysts usually turn their efforts toward important questions.

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Policy and Position Papers, Reviews, and Educational Materials — An Annotated List

Brandow, G.E. "Grain Reserves and the U.S. Economy: A Policy Perspective." *Analyses of Grain Reserves — A*

Proceedings, Economic Research Service, U.S. Department of Agriculture in cooperation with the National Science Foundation. ERS Report No. 634 (August, 1976):92-97.

A delineation of needed information to answer policy questions (sizes of stocks, carrying costs, operational guidelines, complementaries with other food and agricultural policies, and social costs and benefits) and sensitive issues (impacts on producer prices, the livestock industries, and consumer prices). Suggestions for research include models designed to study actuarial aspects of reserves, to determine optimal location, to trace out economic impacts, to simulate operations over time, and to develop decision rules for stock management. However, all questions do not seem answerable by quantitative methods. These include how to balance benefits for producers and consumers, who should own and control stocks, and how to treat foreign food aid.

Cochrane, Willard W. *Feast or Famine: The Uncertain World of Food and Agriculture and Its Policy Implications for the United States.* National Planning Association, Washington, D.C., Report No. 136. February, 1974.

A review and analysis of the world grain market in the early 1970s and the role and experience of the U.S. in that market. Also a proposal for a U.S. grain storage policy to mitigate the problems arising from large fluctuations in grain production is presented. The broad outlines of a price-triggered storage operation are presented and discussed in relation to other U.S. farm, food, and trade policies.

Food and Agriculture Organization of the United Nations. "World Food Security: Proposal of the Director-General." FAO Publication C:73/17, August, 1973.

An urgent appeal to the international community to ensure minimum levels of security against natural disasters. Planned and coordinated grain storage by individual nations is proposed. A forerunner of the World Food Conference in November, 1974.

Food and Agriculture Organization of the United Nations, Committee on Commodity Problems. "Report of the Expert Consultation on Cereal Stock Policies Relating to World Food Security." FAO Publication CCP:75/15, Rome, March, 1975.

Summaries of papers by experts from several nations and a digest of discussions at a conference. The papers explore various aspects of past national and international grain stock practices and advance some new proposals. Conference discussions relate to:

(i) Methods of assessing the desirable size of stocks for food security and ways of sharing the burden of cost between countries.

(ii) Ways of regulating the effects on commercial markets and prices of national stock policies formulated in the context of world food security.

(iii) Ways of balancing the costs of national or regional stocks against the benefits of full or partial insurance in the event of domestic crop failure or other contingencies.

(iv) Criteria for the size and release of separate national emergency stocks for local and/or international relief, including the possibilities of segregating such stocks from commercial markets.

(v) Alternative means by which governments (not holding their own stocks) can encourage private stockholders to meet the official objectives of national stock policies.

(vi) Desirable main elements to be contained or considered in a "model" national stock policy for cereals, compatible with the objectives of world food security, taking account of different types of situations existing in different regions.

Conclusions and recommendations are based mainly on experiences in various countries, positions of international organizations, and on judgments of the experts.

Gray, Roger. "Grain Reserves Issues." Paper presented at the 1974 National Agricultural Outlook Conference, Washington, D.C., Economic Research Service, U.S. Department of Agriculture, December 9, 1974 (mimeographed).

The focus of this paper is on grain reserve issues relevant for commercial importing and exporting nations. It is argued that instability in today's world is likely and its impacts will continue to be undesirable. Hence, reserves can be beneficial. Also, "demand may have become less elastic at higher prices and more elastic at lower prices." As a consequence of the last point, consumers gain and producers lose from reserves.

Hathaway, Dale E. "Grain Stocks and Economic Stability: A Policy Perspective." *Analyses of Grain Reserves — A Proceedings,* Economic Research Service, U.S. Department of Agriculture, in cooperation with the National Science Foundation. ERS Report No. 634 (August, 1976):1-11.

This paper focuses on some of the policy issues that arise when world grain stocks are employed to moderate instability in consumption and in commodity markets. These issues include: (1) the degree of instability; (2) its impact when there are no reserves; and (3) what reserves are likely to cost. An insurance approach to reserves is suggested since reserves are a protection against risk and uncertainty of future supplies. Human suffering and political disaster in poor countries when food is inadequate are viewed as justification for insurance.

International Federation of Agricultural Producers. "Report of the Working Party on the International Grains Arrangement 1974." Washington, D.C., December 15, 1972 (mimeographed).

Recommendations for an international grains arrangement, including provisions for a world grain reserve to assure supplies for importers at agreed-upon prices and for national stocks to absorb impacts of domestic production variation.

Johnson, Robbin S. "Analysis of a Grain Reserve Plan." *Analyses of Grain Reserves — A Proceedings,* Economic Research Service, U.S. Department of Agriculture, in cooperation with the National Science Foundation. ERS Report No. 634 (August, 1976): 157-173.

This paper examines the policy implications of alternative grain management strategies. The primary economic functions for a reserve (supply assurance and price stability) are reviewed. The advantages and disadvantages of private, U.S. government, and international control of stocks are evaluated and U.S. government-held stocks are chosen as the most beneficial. Guidelines for carryover levels and acquisition and release of grain stocks are examined to assess their impact on producers, consumers, taxpayers, and market forces.

Jones, B.F. "Grain Reserves in Agricultural and Food Policy." Purdue University, Agricultural Experiment Station, West Lafayette, Indiana, Bulletin No. 124, May, 1976.

____________. "A Grain Reserve Program." Purdue University, Department of Agricultural Economics, Agricultural Experiment Station, West Lafayette, Indiana, Bulletin No. 137, August, 1976.

Discussion of grain production variability, its consequences, and grain reserve as a policy option is in the first of these two papers. Also covered are the questions to be considered in establishing a U.S. reserve. The second paper describes how a U.S. reserve scheme consisting of 30 million metric tons of grain could be operated to stabilize world markets.

Jones, Brennon. "Needed: An Emergency Food Reserve." Bread for the World Background Paper No. 23, Bread for the World, New York, N.Y., May, 1978.

A summary of arguments favoring grain reserves; a review of U.S. policy developments in 1977 and 1978, and a statement supporting a U.S. government-owned, emergency grain reserve to aid developing nations.

Josling, Timothy. *An International Grain Reserve Policy.* British-North American Committee, 1973.

Reviews the need for international grain reserves, alternative ways of meeting that need, management and financial problems of a reserve, and its effects on the grain market. Because many developing countries do not have the ability to protect themselves from unforeseen food shortages, their needs are viewed as paramount.

Morrow, Daniel T., and Steele, W. Scott. "Toward a World Food Reserve System." Paper presented at International Studies Association meeting, Washington, D.C., February 24, 1978 (mimeographed).

This paper reviews developments leading to the ongoing international wheat agreement negotiations and the issues requiring resolution before a successful conclusion can be reached. (Internationally coordinated wheat stocks held by individual nations are the central element in the proposed agreement.)

National Commission on Supplies and Shortages. *Government and the Nation's Resources.* U.S. Government Printing Office, Washington, D.C., December, 1976, pgs. 150-154. Also see *Studies on Economic Stockpiling.* U.S. Government Printing Office, Washington, D.C., September, 1976.

This report, prepared for Congress, and reprints of two background studies, address the broad issue of future availability of basic raw materials and the role of stockpiling in assuring supplies. In one study the economics of storage is presented in a nontechnical style. The other study focuses on the need to specify stockpiling objectives in a form suitable for implementation. The commission recommends that the U.S. government seek international agreement on grain stockpiling.

Ray, Darryll E. "Managing Instability with Commodity Reserves: A Preliminary Assessment." *Stability: The Continuing Quest.* Proceedings of the Great Plains Agricultural Policy Seminar, Denver, Colorado, May 19-20, 1975. Great Plains Agricultural Council, Publication No. 74, pgs. 89-97.

Government management of grain stocks is supported as a means to stabilize prices. Findings of some research on price stability and stock management are summarized and some areas for further study are suggested.

Sanderson, Fred H. "The World Food Problem: Possibilities of International Action." *Current History* 68 (June, 1975):265-270, 276-277.

A review of the world food situation in the early 1970s and of deliberations in international forums on how to cope with future food shortages. Grain reserve, food aid, and various development programs and proposals are described.

____________. "Economic Stockpiling: Grains." Paper presented at the panel on Economic Stockpiling, sponsored by the Society of Government Economists, New York, N.Y., December 29, 1977 (mimeographed).

Discussion of U.S. policies for domestic grain storage (farmer-held reserve) and proposals for international reserves. The author concluded that reserve levels currently discussed are inadequate for potential world shortfalls. His view is that 70 million metric tons above working stocks is not enough.

Sarris, Alexander H., and Taylor, Lance. "Cereal Stocks, Food Aid and Food Security for the Poor." *World Development* 4 (December, 1976):967-976.

A review of international discussions and negotiations to establish a system of grain reserves and the obstacles to achieving agreement. Also, a scheme is proposed for separate handling of continuing food aid, emergency relief, and a buffer stock to dampen extreme fluctuations in the commercial grain market.

Sharples, Jerry A., and Slaughter, Rudie W., Jr. "Alternative Agricultural and Food Policy Directions for the U.S. with Emphasis on Stability of Prices and Producer Income." *Agricultural and Food Price and Income Policy, Alternative Directions for the United States,* edited by Robert G.F. Spitze. Report of a Policy Research Workshop, Washington, D.C., January 15-16, 1976. University of Illinois at Urbana-Champaign, Agricultural Experiment Station, Special Publication No. 43, August, 1976, pgs. 74-92.

A proposal for establishing a buffer grain stock to stabilize farm and food prices is the core of this paper. Broad outlines of the buffer stock are described and questions needing further research are delineated.

Steele, W. Scott. "Alternative Approaches to Stabilizing International Markets." *Southern Journal of Agricultural Economics* 8 (July, 1976): 57-62.

Causes of and proposed solutions for instability in U.S. grain markets are addressed. The discussion includes unilateral, bilateral, and multilateral approaches. Grain reserve proposals enter into the first and the last. Emphasis is on the need for USSR cooperation because of its historical destabilizing influence on international, hence, U.S., markets.

___________. "Grain Reserves as a Solution to Unstable Markets." Paper presented at the session of the Society of Government Economists, Southern Economic Association Annual Conference, Atlanta, Georgia, November 18, 1976 (mimeographed).

Summary of the issues involved with national and international grain reserves and the policy-making environment in 1976. Alternative means of stabilizing grain markets also are discussed briefly.

Taylor, Lance. "Rich Country Policy and Food Security for the Less Developed World." Paper prepared for the Agricultural Development Council Seminar on "LDC Food Security: The International Response," Reston, Virginia, August, 1978. Massachusetts Institute of Technology, International Nutrition Program, July, 1978 (mimeographed).

Discussion of international food policies of the U.S., of food aid in general, and of the relationship between grain buffer stocks and benefits for the malnourished. International price stability and the assured flow of food to LDCs are seen to be the key benefits of an international buffer stock.

U.S. Congress, House Committee on Foreign Affairs. *International Food Reserves: Background and Current Proposals.* Prepared for the Foreign Affairs and Environmental Policy Division, Subcommittee on International Organizations and Movements, Library of Congress, Congressional Research Service, October, 1974, 93rd Congress, 2nd Session.

Review of U.S. storage and international food aid activities since the 1930s. Contains reprints of grain reserve proposals by Cochrane, Josling, FAO, and the Tripartite group.

U.S. Congress, House Committee on International Relations. *The U.S. Proposal for an International Grain Reserves System.* Report of a staff study mission to the September 29-30, 1975, meeting of the International Wheat Council Preparatory Group, November, 1975, Committee Print, 94th Congress, 1st Session.

___________. *The U.S. Proposal for an International Grain Reserves System II.* Report of a staff study mission to the September 28-October 3, 1977, meeting of the International Wheat Council Preparatory Group, Committee Print, 95th Congress, 1st Session.

Descriptions of previous International Wheat Agreements and two alternative U.S. proposals for an international grain reserve as the core of a future agreement.

U.S. Congress, Senate Select Committee on Nutrition and Human Needs, Comptroller General of the United States. "Grain Reserves: A Potential U.S. Food Policy Tool," March 26, 1976. OSP-76-16.

This report draws upon other empirical research on grain reserves. It describes the uncertainty underlying U.S. grain markets that can lead to too much or too little grain from one year's production to meet domestic and foreign needs. Support is given for a grain reserve, as part of U.S. food policy. Legislative proposals and research on grain reserves are summarized.

U.S. Department of Agriculture, Economic Research Service. "World Food Security and Grain Stocks." *The World Food Situation and Prospects to 1985,* Foreign Agricultural Economic Report No. 98, December, 1974, pgs. 40-47.

Historical world production and import variations are taken as the basis for estimating stock sizes needed to provide food security. Other questions concerning reserve operation and management are discussed also.

U.S. Department of Agriculture, Economic Research Service. "International Food Policy Issues — A Proceedings." Papers presented at the Conference on International Food Policies Issues, held in Washington, D.C., April 28-29, 1977. Foreign Agricultural Economic Report No. 143, January, 1978.

Ten papers from an April, 1977, conference review and assess world food security, past practices and proposals to assist needy nations. How grain reserves mesh with other policies to achieve stable and adequate food supplies is addressed in some papers.

Walker, Rodney, L., and Sharples, Jerry. *Reserve Stocks of Grain: A Review of Research.* U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Report No. 304, August, 1975.

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 response to market conditions and public farm programs; and public vs. private control needs to be examined.