AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Economics

B. SECONDARY: Agricultural economics

2. TITLE AND SUBTITLE

Reserve stock grain models: the world and the U.S., 1975-85

3. AUTHOR(S)

Cochrane, W.W.; Danin, Yigal

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1976	48 p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Department of Agricultural and Applied Economics, and Economic Development Center, University of Minnesota, St. Paul, Minnesota 55101

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

(In Technical Bulletin 305, 1976)

9. ABSTRACT

This study is to provide policymakers with a quantitative picture of an international reserve stock program for grains that has the capacity to provide reasonable stability in world grain prices. To this end, this report presents estimates of the magnitudes of reserve stocks required to achieve alternative price stabilization objectives in world grain markets and the probabilities of their achievement. The empirical work of this study suggests that an international grain reserve stock program could be set up for the period 1975-85 that would hold annual grain price oscillation within a price of perhaps plus 10% and minus 5% of trend, with a probability of 85 to 90%, and with a reserve stock that averaged from 50 to 75 million tons. But to increase further the probability of holding price oscillations within the bounded price range would be difficult and costly, if not impossible. This report is a progress report. More econometric work is needed on the general probabilistic approach used in this study. Further, more work is needed in reformulating, refining, and testing the reserve stock decision rules.

10. CONTROL NUMBER

PN-AAB-933

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Estimating
Food composition
Grain crops
Models
Price stabilization
Reserves

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-2815 211(d)

15. TYPE OF DOCUMENT

Technical Bulletin 305 —1976
Agricultural Experiment Station
University of Minnesota

RESERVE STOCK GRAIN MODELS, THE WORLD AND THE UNITED STATES, 1975-85

Willard W. Cochrane
Yigal Danin

CONTENTS

PART I.	Summary and Conclusions	3
PART II.	The General Analytical Approach	4
PART III.	The Models	4
PART IV.	The Reserve Stock Decision Rules	6
PART V.	Price Stabilization Probabilities and Stock Requirements: The Empirical Results	7
PART VI.	Some Policy and Organizational Issues	22
PART VII.	Technical Discussion of Computational Procedures	24
APPENDIX A.	Tables	30
APPENDIX B.	A Flow Chart of the Computational Program	36
REFERENCES		48

PN-AA 5-933

RESERVE STOCK GRAIN MODELS, THE WORLD AND THE UNITED STATES, 1975-85

Willard W. Cochrane
Yigal Danin

PART I. SUMMARY AND CONCLUSIONS

It is the purpose of this study to provide policymakers with a quantitative picture of an international reserve stock program for grains that has the capacity to provide reasonable stability in world grain prices. To this end we present estimates of the magnitudes of reserve stocks required to achieve alternative price stabilization objectives in world grain markets and the probabilities of their achievement.

Assuming that the price elasticity of demand for all grains on a world basis is −.1 and that fluctuations in total grain production from 1975 to 1985 will approximate in magnitude those for the period 1950-73, market prices could be expected to vary about the mean equilibrium price (hereafter called target price) by about 27 percent per year. The introduction of a reserve stock program reduces the annual market price variability around the target price. How much depends upon the specific formulation of the reserve stock decision rule employed (see Part V, tables 1-11). A reserve stock rule that states that stocks will be acquired and released, insofar as it is possible, to hold market prices within the range, *plus or minus 10 percent of the target price*, reduces the annual market price variability to 15 percent by 1980 and to 14 percent by 1985. A bounded price reserve stock rule of the specific form, *plus 10 percent, minus 5 percent of the target price*, reduces the annual market price variability to 13 percent by 1980 and to 12 percent by 1985. A differently conceived rule, that we define as the *price variability minimization rule*, makes each action leading to a change in the size of stocks a function of (1) the size of the reserve stocks at that time and (2) the current price. The application of this rule, in a specific maximum effort formulation, reduces the annual variability of market prices to 13 percent by 1980, where it holds constant at 13 percent until 1985 (see table 6).

The *average* size of the reserve stock in the first formulation mentioned above ranges from approximately 38 million tons in 1980 to 57 million tons in 1985. In the second formulation it ranges from approximately 51 million tons in 1980 to 73 million tons in 1985. In the third formulation it ranges from 47 million tons in 1980 to 62 million tons in 1985. Other specifications of the bounded price rule and the variability minimization rule were also examined. These provide a spectrum of program results with regard to the degree of price stabilization and the level of reserve stocks.

In more general terms, the empirical work of this study suggests that an international grain reserve stock program could be set up for the period 1975-85 that would hold annual cent and minus 5 percent of trend, with a probability of 85 to 90 percent, and with a reserve stock that averaged from 50 to 75 million tons. But to increase further the probability of holding price oscillations within the bounded price range would be difficult and costly, if not impossible. To increase the probability of holding market price oscillations within the defined price range would require the holding of a much greater volume of stocks on the average. But the acquisition of such volumes of stocks for the reserve stock program would in itself cause market prices to move away from the mean equilibrium price. Thus, this study indicates that it is feasible, through the implementation of an international grain reserve stock program, to greatly reduce annual grain price fluctuation, but it is extremely difficult, if not impossible, to reduce those fluctuations below an average of 12 percent per year.

The grain reserve stock issue is a thorny issue. This is true both within countries and among countries. Producer interests currently are wary of price stabilizing schemes and are reluctant to consider them seriously unless they involve price floors but no ceilings. Consumer interests, on the other hand, currently seek stable grain and food prices and are anxious to implement reserve stock programs to achieve stable grain prices at levels that seem reasonable to them. Consumers tend to believe, and perhaps rightly in these days of resource scarcity, that they have much to gain from the stabilization of producer prices. Whether these opposing interests can be reconciled in an effective international grain reserve stock program remains to be seen. But if they are reconciled and if an effective international reserve stock program is brought into being, it will occur only because of extraordinarily wise and strong leadership [illegible] the part of one, or a few, key trading nations (for example, [illegible] United States) in the world market. To date no important trading nation has provided that leadership.

This report is a progress report. More econometric work is needed to estimate the parameters employed in the models, and more development work is needed on the general probabilistic approach employed in this study. Further, more work is needed in reformulating, refining, and testing the reserve stock decision rules. We believe all this could best be done by a research team in the U.S. Department of Agriculture; that is where the needed professional manpower and the necessary data are. Nonetheless we believe that the various estimates of market price probabilities, price variability, and reserve stock magnitudes developed and presented in this study are useful in suggesting what can and cannot be accomplished in the way of market price stabilization through a reserve stock program

PART II.
THE GENERAL ANALYTICAL APPROACH

The focus of this study is on stabilizing world grain prices through a reserve stock program. The focus is on world grain prices and their stabilization not because world grain prices are necessarily the most critical factor to producers and consumers of grains and grain products, but because grain prices and changes in those prices best indicate the state of grain supplies in the world and changes in supply relative to demand. Thus, the focus of this study leads naturally and directly to a supply and demand type of analysis.

The general approach taken for developing estimates of reserve grain stocks and the associated probabilities for achieving different price stabilization objectives may be stated as follows. First, a simple supply and demand model of the grain market under consideration was formulated. This supply and demand model then was used to determine market prices (i.e., those prices that satisfy equilibrium conditions). Disturbance factors were introduced into this basic model that randomly shift the demand and/or supply and generate as a result a probability distribution of market prices in a free market situation (i.e., with no intervention).

Second, different reserve stock decision rules were applied to the free market probability distribution of prices. The application of a given stocks rule to the free market distribution changes the distribution and generates a new probability distribution of prices associated with the particular stocks rule under discussion.

Finally, we analyzed the altered probability distribution to learn to what degree the variability in market prices is reduced or the price stabilization objective is achieved. Measures of the degree to which the price stabilization objective is achieved and the probabilities of achievement are presented in several forms. Estimates of the size of the reserve stock required to achieve a specific price stabilization objective with some probability are also presented for each decision rule.[1]

The procedure was applied first to a model of world grain market in total and by principal categories of wheat, rice, and coarse grains. It was also applied to the United States wheat market. The models used are described in Part III.

No econometric work was undertaken in this study to estimate the models mentioned above. Judgments were exercised in the selection of specific demand and supply parameters, but the specific parameters selected for use in this study are based on estimates commonly used in agricultural price analyses. In some cases alternative parameters were employed to test the sensitivity of the analysis to differently valued parameters. Thus, the models developed and employed in this analysis were conceived not to yield unique solutions, but to illustrate procedures for continuously investigating the problem as well as yielding estimates that illustrate the possible magnitudes of the grain reserve problem.

In this study then, we do not find unique answers to the related questions: what kind of a reserve stock program should we have and what should be its size? One reason we did not obtain such answers was lack of time and resources. But more importantly, there are probably no uniquely best answers to these questions. But we do come out with some estimates that illustrate the program magnitudes and characteristics that would be involved in a stabilization effect under alternative stocks rules and under different assumptions regarding price elasticities and size of beginning reserve stocks. We also develop a general analytical approach to an analysis of the reserve stock problem that we believe merits further development and refinement. Thus, from this study policymakers can begin to learn the cost and quantity implications of an international reserve stock program, and research workers should find an approach and leads to further productive work on the reserve stock problem.

[1] For a different general approach see the recent study by Jerry A. Sharples and Rodney L. Walker, *Analysis of Wheat Loan Rates and Target Prices Using a Wheat Reserve Stocks Simulation Model*, CED Working Paper, Economic Research Service, USDA, May 1975.

PART III. THE MODELS

Two specific models, a world grains model and a United States wheat model, were formulated and used in this study to derive empirical estimates of the various magnitudes of a reserve stock program for the grains. Each of these specific models is a variation of the same basic model. This basic model is described immediately below, and the world and U.S. models are elaborated upon in the sections that follow.

The basic model. – The basic model includes a demand function and a supply function for a single commodity. These functions include shifters of two kinds: systematic shifters that move the functions through time (i.e., growth factors) and disturbances that randomly shift the function back and forth. All variables except price and quantity are assumed to be exogenous to the model and are included either in the growth factors (e.g., systematic income and population growth effects on the demand and systematic technical change on the supply) or in the random disturbance (e.g., weather effect on yields, nonsystematic changes in trade policies, nonsystematic price effects of complements and substitutes).

Price is determined at the intersection of the demand and supply; it therefore fluctuates due to the systematic and random changes in the demand and supply. A stocks program is introduced that influences the price by adding to the supply when stocks are sold or by adding to the demand when stocks are acquired. An analysis of the activity of such a program is the core of this study. The complete basic model is described formally below. However, the nonprofessional reader can skip the rest of this section without a loss of continuity.

Demand function at time t

$$Y_t = [\phi(P_t) + e_{dt}]\,(1 + g_d)^t \tag{1}$$

where

Y_t = quantity demanded at time t,
P_t = price at time t,
$\phi(P_t)$ = mean of demand function at $t = 0$, $\phi'(P) > 0$,
e_{dt} = random disturbance term,
g_d = demand's rate of growth.

It is assumed that e_{dt} is distributed according to a known probability law, represented by $f_d(e_{dt})$, which is a probability mass function (in the case that e_{dt} is a discrete random variable) or a probability density function (if e_{dt} is continuous). It is assumed that $f_d(e_{dt})$ is identical for all t, that e_{dt} has zero mean and that any two disturbances of two periods, e_{dt} and $e_{dt'}$, are mutually independent.

All the exogenous factors that cause a systematic shifting of the demand function are assumed to be included in g_d (e.g., population and income effects), while all other exogenous determinants of the demand are included in e_d. (For example, if the demand includes a demand for export, the randomness might be due to weather effect on yield abroad, or e_d might be caused by unsystematic changes in prices of complements and substitutes, etc.)

Supply function at time t

(2) $$X_t = [\psi(P_{t-1}) + e_{st}]\,(1 + g_s)^t$$

where

X_t = quantity supplied from production at time t,
P_{t-1} = one-period-lagged price at time t,
$\psi(P_{t-1})$ = mean of supply function at t = 0,
$\psi'(P_{t-1})$ = > 0,
e_{st} = random disturbance term,
g_s = supply's rate of growth.

e_{st} is distributed according to a probability law represented by $f_s(e_{st})$, which is a probability mass function or a probability density function (if e_{st} is discrete or continuous, respectively). $f_s(e_{st})$ is identical for all t, and for any two periods $t \neq t'$, e_{st}, and e_{st} are mutually independent. In addition, e_{st} and e_{dt} are independent for all $t \neq t'$.

As in the demand case, it is assumed that all of the exogenous factors of supply that are changed systematically with time are included in g_s (e.g., systematic technical change) and all other exogenous determinants of supply are included in the random disturbance e_s (e.g., weather effect on yields).

In summary, it is a simple "cobweb" model. For convenience, let us use the following notation:

$$\phi_t(P_t) \equiv \phi(P_t)\cdot(1 + g_d)^t$$
$$\psi_t(P_{t-1}) \equiv \psi(P_{t-1})\cdot(1 + g_s)^t$$
$$\epsilon_{dt} \equiv e_{dt}\cdot(1 + g_d)^t$$
$$\epsilon_{st} \equiv e_{st}\cdot(1 + g_s)^t$$

and rewrite the demand and supply functions:

(1') $$Y_t = \phi_t(P_t) + \epsilon_{dt}$$

(2') $$X_t = \psi_t(P_{t-1}) + \epsilon_{st}$$

Let us denote the stocks (i.e., program stocks in addition to working stocks) at the end of period t by C_t (the beginning stocks at t are C_{t-1}).

Given the lagged price, P_{t-1}, and the values of the random disturbances ϵ_{dt} and ϵ_{st} at time t, the price is determined by the equilibrium condition:

$$Y_t + C_t - C_{t-1} = X_t,$$

or

(3) $$\phi_t(P_t) + \epsilon_{dt} + \Delta c_t = \psi_t(P_{t-1}) + \epsilon_{st}$$

where

$\Delta c_t \equiv C_t - C_{t-1}$ is the change of stocks at t.

Define the "free market price" to be the equilibrium price when $\Delta c_t = 0$ and denote it by $\tilde{P}_t$.

$\tilde{P}_t$ is defined by

$$\phi_t(\tilde{P}_t) + \epsilon_{dt} = \psi_t(P_{t-1}) + \epsilon_{st},$$

or

(4) $$\tilde{P}_t = \phi_t^{-1}[\psi_t(P_{t-1}) + \epsilon_t]$$

where

ϕ_t^{-1} is the inverse demand function and $\epsilon_t \equiv \epsilon_{st} - \epsilon_{dt}$ is the combined disturbance of supply and demand. ϵ_t is distributed according to a probability law represented by $f_t(\epsilon_t)$, which is derived from $f_d(e_d)$, $f_s(e_s)$ and the definitions of ϵ_{dt} and ϵ_{st}.[2]

Equation (4) describes the "free market price" as a function of the lagged price P_{t-1} and the disturbance ϵ_t. Given P_t, beginning stocks C_{t-1} and carryover stocks C_t, the price P_t is determined by the equilibrium condition (3).

The world model. The different grains are close substitutes on the demand side and in some cases on the supply side too. Therefore, a model of the world grain market must include all the grains. For example, if wheat production falls short of anticipated utilization, users of wheat will begin to substitute rice and coarse grain for wheat, in which case the price rise of wheat is moderated as all grain prices move up. An effort to stabilize the price of one grain will affect the price of other grains via the substitution process. Ideally, it would be desirable to include explicitly and simultaneously the different categories of grains in the model, disaggregated as to countries and areas. However, methods and capacity of computation procedures prevented us from managing such a detailed model. Thus, a highly aggregative and simplified model was formulated. In the world model under consideration, *all grains* are considered as one great, aggregative commodity.

In this model, world trade is assumed to be conducted within one large market for a single aggregative commodity, grains, in which no important barriers to trade exist. All categories of grains move readily between and among areas in response to need as indicated by market prices.

The world demand for grains is assumed to be nonstochastic and sensitive to price (i.e. has slope). The form of the demand curve is linear. In the empirical analysis, we operated the model with two different assumed price elasticities of demand specified at average prices and quantities: -.1 and -.2.[3] The world grain production is assumed to be stochastic and completely price inelastic. It grows at a constant annual rate of approximately 3 percent. This rate was estimated on the basis of a logarithmic trend that was fitted to the observations of world grain production for the period 1950-73. The probability distribution of production is assumed to be normal. The variance of it was estimated using the fluctuations around the trend. For each year in the projected period 1975-85, then, world grain production could be of any magnitude with the associated probability in accordance with the probability distribution of production discussed above.

[2] For example: if $e_d \sim N(0, \sigma_d^2)$ and $e_s \sim N(0, \sigma_s^2)$ then $\epsilon_t \sim N(0, \sigma_t^2)$, where $\sigma_t^2 = (1 + g_d)^{2t}\sigma_d^2 + (1 + g_s)^{2t}\sigma_s^2$.

[3] The judgments that produced these price elasticity of demand assumptions were based on estimates presented for different categories of grain and different areas of the world in *World Demand Prospects for Grain in 1980, with Emphasis on Trade by the Less Developed Countries*, Foreign Agricultural Economic Report No. 75, ERS, USDA, Washington, D.C., December 1971, p. 35.

We assumed that the world demand for grains grows at the same annual rate of growth as the supply, approximately 3 percent. In this model, then, we have neither an upward nor downward trend in the price of grain for the period under discussion, 1975-85. Under this assumption, the analysis focuses exclusively on annual fluctuations in production and the resulting short-run variation in grain prices. The price at which supply and demand intersect in 1975 is defined as 100. Thereafter, the equilibrium mean price remains at 100 over the period 1975-85, because the demand and mean supply grow at equal rates.

The empirical results that flow from applying a given stocks rule to the world market model for all grains are presented in Part V. We also experimented with similar models applied to separate categories of grains, namely wheat, rice, and coarse grains. The limitation of such commodity analyses for the world grain market is, however, clear from the discussion at the beginning of this section. The results of the commodity analyses are summarized in Appendix A.

The U.S. wheat model. The U.S. wheat model is a simple demand and supply model of a one-period cobweb type.[4] Prices and quantities are determined by the model. All other factors are assumed to be exogenous and are included either as "shifters" that systematically shift the demand and supply functions through time, or in stochastic disturbances that shift the functions randomly in accordance with some known probability law.

The demand equation is linear and is composed of a domestic and an export component. The domestic component is assumed to be nonstochastic and grows at a rate of 1 percent per year. The export component is assumed to be stochastic, and the disturbance is assumed to be normal with a constant relative standard deviation. Export demand is assumed to grow at an annual rate of 3 percent per year. Total demand for each year is the sum of the domestic and export demands. In the empirical analysis, we operate the model with an assumed price elasticity of domestic demand equal to -.378 and an assumed price elasticity of export demand equal to -.5. The price elasticity of total demand in 1975 equals -.43. This measure of price elasticity changes over time as the export share of total demand increases.

The supply relation is composed of an acreage supply function and a yield-per-acre function. Wheat acreage in the acreage supply function is assumed to be a function of price lagged 1 year. Yield per acre is assumed to be stochastic and normally distributed and to increase at a constant rate of approximately 3 percent per year. Supply for each year is equal to the wheat acreage times the yield.

In the U.S. wheat model, price trends downward over the period 1975-85 because it is assumed that the supply will increase more rapidly than demand. But the investigation continues to focus on short-run production variability and the impact of that variability on wheat prices. Random production disturbances enter the U.S. wheat model through both the demand and supply sides. Variability in yield per acre within the U.S. enters the model as a disturbance factor in the supply equation. Production variability outside the United States enters the model through random shifts in the export demand for U.S. wheat.

[4] Due to lack of time and resources, the investigation at this stage was limited to one grain category, wheat.

PART IV. THE RESERVE STOCK DECISION RULES

Each grain market model includes random disturbances, the probability distribution of which is assumed to be known. For each value of the disturbance, the model generates an equilibrium price. The probability distribution of the disturbances is then translated into a probability distribution of prices. This latter distribution we call the free market price distribution.

The free market price distribution is then changed, or modified, by applying some reserve stock rule to it. This change is effected by the acquisition or the release of stocks, thereby modifying the net supply of grain available to the market in the year in question. This in turn affects the market price and creates a new probability distribution of prices. Let us therefore look at two stocks rules and their several specific formulations that were applied to the market models in this study.

The bounded price rule. — This simple rule states that insofar as stocks are available, market prices will not be permitted to oscillate outside a defined, or bounded, price range.[5] As used in this analysis, the rule states that whenever market price falls below the lower boundary of the price stabilization range, supplies must be acquired under the program in sufficient quantities to hold the price at the lower boundary. The rule also states that whenever market price rises above the upper boundary of the price stabilization range, supplies must be released, to the extent that they exist, to hold the price at the upper boundary. In practice, a grain price stabilization agency might deem it wise to start acquiring stocks before the market price had fallen to the lower boundary or to start releasing stocks before the market price had reached the upper boundary. But this kind of administrative flexibility is not investigated in this analysis.

Several specific formulations of the bounded price rule were investigated in this study, and the results of these different formulations are reported in Part V. A series of target prices for the years 1975-1985 was defined to be equal to the mean equilibrium prices, which in this analysis are always equal to 100. The boundaries of the price range are then defined in relation to the target prices of 100. We investigated and report in Part V on four specific formulations of the bounded price rule:

1. Plus or minus 10 percent of the target price,
2. Plus or minus 20 percent of the target price,
3. Plus 10 percent and minus 5 percent of the target price,
4. A limitation on the volume of stocks held at all times to 3 percent of world production.

Countless other specific formulations of the bounded price rule might be investigated given the interest, time, and funds. Certainly, an agency that had the responsibility for administering a reserve stock program would want to investigate other specific formulations.

[5] The "insofar as possible" clause might include operating funds as well as stocks, but we do not investigate a possible financial limitation in this analysis.

The price variability minimization rule.[6] – The price variability minimization rule, as developed in this study, is a reserve stock decision rule of compelling logic. But it is a difficult rule to explain. A price-instability index is defined that measures the degree of instability of a series of future prices around a series of target prices.[7] The objective of a stocks policy in this study is to reduce the instability of this whole array of prices (as measured by the instability index). The ability to stabilize prices depends of course on the availability of adequate stocks. The more stocks, the more stability that can be achieved. On the other hand, holding stocks involves the bearing of costs, which is socially undesirable. In this context, an efficient stocks policy is one that, for a given degree of price instability, minimizes the mean cost, or equivalently, for a given mean cost minimizes the degree of price instability. It can be argued that an efficient stocks rule, i.e., the decisions to acquire stocks or to release stocks in a given year, should be dependent upon two indicators: (1) the size of reserve stocks at the beginning of the year and (2) the level of grain prices within the year. In other words, price stabilization decisions in any year are made a function of the price of the commodity at that time and the size of reserve stocks available for use. For each combination of these twin indicators, a computation program was composed to compute the appropriate change of stocks that leads to efficiency as defined above.

No single, unique efficient stocks policy may be said to exist, because as one increases the mean stocks (and the costs), one is able to achieve a greater reduction of price instability. It is a subjective matter as to which combination of mean stocks and degree of instability to choose from the set of all efficient combinations. In principle, it is desirable to reduce the degree of price instability as long as the marginal value of this reduction is greater than the cost of achieving it. Thus, measuring or accounting for this subjective valuation of instability becomes important in selecting an efficient combination of average program costs and the associated degree of price instability. Let λ be an indicator of the marginal valuation, relative to costs, of a given change in the degree of price stability achieved through a stocks program. In this context, λ can take on values between 0 and infinity (positive). A large λ means a high subjective valuation of price stability relative to the costs of achieving it, hence a willingness to pay a high cost to avoid instability. Similarly, a small value of λ reflects a low subjective valuation of more stability relative to the costs of achieving it and, hence, a greater tolerance for price instability. The greater λ is, the greater will be the mean stocks and the smaller will be the degree of instability corresponding to that λ.

For a given λ, the computer program gives the stocks rules in the form of tables that indicate, for given prices and given beginning stocks, the appropriate change of stocks (i.e., acquisition or sales). The program was applied with several alternative λ's. We do not present the corresponding tables of all possible stocks rules in this report. An analysis of the effects of applying the price variability minimization rules corresponding to different λ's is given in Part V and summarized in tables 6 and 7 of Part V.

The probability estimates and measures of price variance and stock magnitudes presented in tables 6 and 7 of Part V should be viewed as preliminary. The procedures for analyzing the application of the price variability minimization rule to a market situation need to be further developed, refined, and tested. But the estimates presented in tables 6 and 7 of Part V are not without meaning. They suggest the program magnitudes that would be involved for certain assumed conditions regarding price elasticity, size of beginning reserve stocks, and willingness to accept program costs in the achievement of different levels of price stability where two criteria for making decisions to acquire or release stocks are employed: (1) the price of the commodity and (2) the size of the beginning reserve stock. Such estimates are of interest to everyone concerned with the reserve stock problem, but this type of analysis, properly interpreted, could be of valuable assistance to the managers of an operating reserve stock program, because the managers of a reserve stock program would need to consider the size of the reserve stock on hand in their pursuit of the price stabilization objective.

PART V. PRICE STABILIZATION PROBABILITIES AND STOCK REQUIREMENTS: THE EMPIRICAL RESULTS

As discussed in Part IV, we investigated in this study the application of two different reserve stock decision rules to a world model of a free market situation. And we experimented with several different specific formulations of each rule. The results of those experiments are presented below.

Following the argument presented in Part III, we limit our discussion of the world model to the category *all grains*. However, we experimented with the commodity categories, namely wheat, rice, and coarse grains. Those interested in the results of these commodity analyses may review them in Appendix A.

The world model: the bounded price rule. Let us turn first to the application of the bounded price rule. We will look at a specific formulation that involves a very low price elasticity of demand (.1), no beginning reserve stocks, and a price stabilization range of plus or minus 10 percent of the target price 100 (see table 1). The application of this formulation of the bounded price rule reduces the price variation around the target price in 1975 from 27.4 percent in the free market situation to 20.4 in the stabilization situation.[8] By 1980 the variation around the target price is reduced to 15.4 percent under the stabilization program and remains at that approximate degree of variation through 1985.[9] The proba-

[6] The theoretical concept and implications of this rule are discussed in detail by Yigal Danin in Staff Paper P75-30, "Grain Reserves and Price Stabilization," Department of Agricultural and Applied Economics, University of Minnesota, 1975.

[7] There are many ways to define a quantitative instability index. Naturally all of them are rather arbitrary, and choosing one is a subjective matter. In this study we measure the instability of a series of future prices by the mean of square deviations of the prices from the series of target prices. This measure was used also in the analysis of the bounded price rule.

[8] To reduce the mass of data to be presented in this report, we consistently throughout the investigation ask the computer to provide results for only 3 years, 1975, 1980, and 1985.

[9] If these magnitudes of price variability seem inconsistent with the price stabilization boundaries of plus or minus 10 percent, remember that sufficient stocks are not always on hand to hold the free market price within the upper price boundary. From table 1 it may be observed that the probability of market price being within the price stabilization boundaries of plus or minus 10 percent is 81 percent in 1980 and 85 percent in 1985.

bility of the market price remaining within the price stabilization range increases from 65 percent in 1975 to 81 percent in 1980 and to 85 percent in 1985. The average reserve stock held in a particular year increases from some 9 million tons in 1975 to 57 million tons in 1985. The 1985 figure amounts to 3.2 percent of world grain production.

Two comparisons are provided in table 1: a formulation with a bounded price range of plus or minus 20 percent of the target price of 100 and a formulation of plus 10 and minus 5 percent of the target price of 100. The wider bounded range allows the variation in the market price around the target price to increase as one might expect. A bounded price decision rule of plus or minus 20 percent of the target price seeks to achieve less in the way of price stabilization, and that is what it does. The bounded price decision rule, plus 10 and minus 5 percent, on the other hand, is a more restrictive rule, and it achieves more in the way of price stabilization. Variation around the target price is reduced to approximately 12 percent by 1985, compared with 19 percent for the plus or minus 20 percent rule, with 14 percent for the plus or minus 10 percent rule, and 27 percent for the free market. But the average cost of stabilization goes up. The average reserve stock under the plus 10 minus 5 percent rule approximates 73 million tons in 1985 compared with average reserve stocks of 39 million tons under the plus or minus 20 percent rule, and 57 million tons under the plus or minus 10 percent rule.

A careful study of table 1 suggests some important conclusions regarding the possible magnitudes of an international price stabilization effort for the grains.

If the price elasticity of demand for all grains does in fact approximate −.1 and if the beginning reserve stock is zero and the only criterion for acquiring or releasing stocks is the current price, then:

1. It is exceedingly difficult to reduce annual price variations around the price target below 10 percent.
2. But a careful formulation of the price stabilization boundaries (for example, plus 10, minus 5 percent) would permit an international stabilization program to reduce annual variations around the target price to close to 10 percent where the average reserve stock approaches 75 million tons.

If the stabilization effort begins with some stocks, say 20 million tons, then we see that market price variations around the target price decline significantly in 1975, which was not the case where there were no beginning reserve stocks (table 2). This, of course, is what we would expect to happen. The effect of the beginning reserve stocks is largely, but not entirely, dissipated by 1980. In table 3 we see the effect of a large beginning reserve stock — a stock of 50 million tons. Such a large beginning reserve stock drastically reduces the variation in market prices around the target price in 1975. But thereafter the variation increases, and the variation in 1985 with a beginning reserve stock of 50 million tons is not greatly different from that with a beginning reserve stock of 20 million tons, or for that matter, with a zero beginning reserve stock situation.

The estimates presented in tables 2 and 3 indicate that some beginning reserve stock is desirable if a reduction in market price variability is sought for the immediate future, but that a very large beginning reserve stock achieves little in the way of long-run price stabilization results, hence should be avoided if program costs are an important consideration.

In table 4 the consequences of limiting the reserve stock accumulation at all times to not more than 3 percent of total world grain production are investigated. The consequences are clearly unsatisfactory. The operation of a 3 percent limitation at all times restricts the accumulation of stocks of greater than 3 percent at certain times and thus has the effect of holding the average available reserve stock to such low levels, to 1.5 percent or less, that little is achieved in the way of price stabilization. The annual variation in market price around the target price in this formulation is close to 20 percent. If a limitation of this type were imposed upon the managers of an international stabilization program, it would certainly need to be greater than 3 percent of annual production, and some operational experience with a stabilization program should be gained before a rigid limitation on stock accumulation was made mandatory.

The implications of the price elasticity of demand for grains in the world market being larger than −.1 are explored in table 5; the price elasticity of demand in table 5 is assumed to be −.2. As would be expected, the price elasticity of demand has important implications for the whole issue of price stabilization. Increasing the measure of price elasticity from −.1 to −.2 reduces the market price variation around the target price in the free market situation from approximately 27 percent to 14 percent. Price variability in the free market is cut almost in half. And the application of a bounded price rule of plus or minus 10 percent of the target price, with a beginning stock of 20 million tons, reduces the annual variation around the target price to close to 9 percent for each of the years 1975, 1980, and 1985. To achieve this degree of price stabilization the average size of the reserve stock approximates 33 million tons in 1980 and 45 million tons in 1985. In sum, if we assume the price elasticity of demand for all grains is equal to −.2, then the need for a price stabilization program is greatly reduced and any degree of price stabilization is achieved more easily than it is with an assumed price elasticity of −.1.

We did not try to answer the question in this study of what the true price elasticity of demand is for all grains in the world market. And the question will not be answered easily. But if it turns out from research efforts, or experience with international grain stabilization programs, that the true elasticity of demand for all grains is closer to −.2 than it is to −.1, then the difficulties and costs of operating an international grain stabilization program would not be unduly great. In a similar fashion, the pressures to operate such a stabilization program would not be great either. Relaxing the elasticity assumption reduces the acuteness of the whole problem. And a new set of issues and problems is opened up for the econometricians.

The world model: variability minimization rule. — The minimization rule, it will be recalled, takes account of the beginning reserve stock position and current prices in its directives to the managers about acquiring or releasing stocks at any point in time, where the managers seek to pursue an efficient stocks policy. An efficient stocks policy is a policy in which price instability is minimized given the average stocks or, equivalently, stocks are minimized, given the degree of price instability. As mentioned in Part IV, any minimization rule can be specified by the marginal valuation of stability relative to costs such that the greater the marginal valuation of stability, the greater the average reserve stock held and the smaller the degree of instability experienced. Several alternative specifications were examined, and tables of the reserve stock decision

rules were provided by the computer.[10] These tables are not presented in this report. However, tables similar to tables 1 through 5, which summarize the expected results from the application of the rules, are given in tables 6 and 7 for zero and 20 million tons of beginning reserve stocks respectively.

In tables 6 and 7, the column indicated by infinite valuation of stability relative to costs refers to a minimization stocks rule that seeks to minimize price instability for the entire planning period 1975-85, no matter what the costs may be. As one moves in the tables toward a lower valuation of stability relative to costs, instability increases and the size of the reserve stock decreases.

It is important to recognize that the variability minimization stocks rule for each valuation of stability relative to costs in tables 6 and 7 seeks to minimize price variability for the entire period under consideration, not necessarily the variability in a particular year. For example, in 1980 and 1985 the instability index (variation around target price) increases when the valuation of stability decreases (moving from left to right in tables 6 and 7), and stocks decrease as the valuation of stability relative to costs declines. However, in 1975 the greatest variation of price around the target price is associated with infinite valuation of stability relative to costs, which would seem to be contrary to the logic of the minimization stock decision rule. The explanation is that when the beginning reserve stocks are small, there is a motivation to increase stocks for future contingencies, even if that increase in stocks results in a 1975 price that is higher than the target price and thus in greater variability around the target price. This motivation to increase stocks in 1975 is the greatest when the valuation of stability relative to costs is highest, which explains the apparent contradiction under discussion.

It will be observed in table 6 that variations in market prices around the target price are reduced from about 27 percent in the free market in 1975 to about 13 percent in 1980 and 1985, where world society is willing to make the maximum effort to achieve price stability in the grains and there are no beginning reserve stocks. This degree of price stabilization compares with 15 percent and 14 percent in 1980 and 1985 respectively for plus or minus 10 percent under the bounded price rule (see table 1), and 13 percent and 12 percent respectively for plus 10 percent and minus 5 percent. Thus, we achieve a shade greater degree of stabilization under the maximum formulation of the minimization rule. But in other formulations of the minimization rule, there is not much to choose between those formulations and the bounded price rule, plus or minus 10 percent, with respect to price stabilization.

In terms of efficiency, the minimization rule again holds a slight edge over the bounded price rule. For example, the minimization rule with the specific formulation, moderate valuation of stability relative to costs, achieves a degree of variation around the target price of about 14 percent in 1985 with a reserve stock that averaged 1.8 percent of world production. The bounded price rule with the formulation, plus or minus 10 percent, achieves a degree of variation around the target price of about 14 percent in 1985 with a reserve stock that averaged 3.2 percent of world production. Such comparisons are not conclusive because the data given in tables 1 and 6 are only partial. One should look at the whole planning period and not at a sample of years.

The question might be asked regarding the first formulation presented in table 6, infinite valuation of stability relative to costs, why the program does not accumulate larger reserve stocks in the early years, say 1975, and thereby reduce future variation around the target price still further. The way the world model was constructed, the average free market price is 100 in each year from 1975 to 1985, hence the target price is 100 in each year. But the act of acquiring stocks for the reserve itself tends to push the market price away from the target price if the first price is already equal to or greater than the latter price. This may be observed in table 6 opposite the side heading, average market price. The act of acquiring reserve stocks in 1975 pushes the average price up to 116, then the average market price falls back toward 100 as the years pass and the pressure to acquire stocks for the reserve is reduced. Thus, the answer to the question posed above is to be found in the fact that any greater stock accumulation under the stabilization program would have the effect of destabilizing world market prices in the first years of the planning period. Given the assumed conditions of the world market, the specific formulation, infinite valuation of stability relative to costs, under the minimization rule, has specified the specific stock acquisition and release operations that minimize the variation in prices around the target price on the average for the period 1975-85.

The minimization rule is investigated in table 7 under the assumed condition of beginning reserve stocks of 20 million tons. As we observed in the case of the bounded price rule, the existence of 20 million tons of reserve stocks at the beginning of the program of price stabilization greatly reduces the degree of price variability in the 1st year, 1975. But the effect of beginning stocks of 20 million tons is minimal by 1980.

The effects of assuming a price elasticity of demand of −.2 in the world model with an application of the price variability minimization rule were not investigated. But there is no reason why the basic effect of the assumption of a higher price elasticity in the world model should be any different with the application of the minimization rule than was the case with the application of the bounded price rule. Assuming a higher price elasticity of demand, price variability in the free market situation should be less, the pressure for a price stabilization program should be less, and the operation of the price stabilization program should be easier and less costly. The assumption of a higher price elasticity in the world model reduces the degree of price variability in the free market, regardless of the reserve stock decision rule applied to achieve a particular stabilization objective.

The application of the price variability minimization rule suggests the importance of considering the current stock position, as well as the current market prices, before taking a change of stock action to stabilize current grain market prices. Even if the bounded price rule were adopted as the decision rule in a stabilization program, perhaps because of its simplicity of presentation and understanding, good management practice would suggest the undertaking of research along the lines indicated by the minimization rule. From such an analysis, the managers of the stabilization program would gain information about the desirability of acquiring or releasing stocks *within* the price boundaries and about the need for

[10] These reserve stock decision rules state for each combination of current price and size of beginning stock what the managers should do in the way of acquiring or releasing stocks.

permitting certain exceptions to the stocking actions at the price boundaries. This is the case because the analysis involved in the application of the minimization rule indicates what should be done in the way of acquiring or releasing stocks *now* to achieve the maximum degree of price stability over the entire future period under consideration.

The United States wheat model. -- The United States model is not developed as fully as the world model. An *all grains* variation of the model, for example, was not constructed. A model was constructed for what appeared to be the easiest commodity to handle, namely, wheat. Both the bounded price rule and the price variability minimization rule were applied to the U.S. wheat model. The tentative results are presented in tables 8-11.

In table 8 we investigate the application of the bounded price rule with the assumption of no beginning reserve stocks and a price elasticity of total demand of -.43 for 1975 (thereafter the price elasticity increases modestly each year, as the export share of the market increases). The variation in the market price for wheat around the target price in the free market situation is very large — approximating 44 percent in 1975, 51 percent in 1980, and 56 percent in 1985. The application of the bounded price rule with the specific formulation, plus or minus 10 percent of the target price, reduces the price variability of wheat in the U.S. market significantly (table 8). The variation in the market price of wheat is reduced to approximately 22 percent by 1985 by the application of the plus or minus 10 percent formulation, compared to 56 percent variability under the free market.

The average reserve stock under this formulation is large, but not unduly large when compared with wheat reserves for the United States that have been suggested in the past. The average reserve stock indicated under the plus or minus 10 percent formulation is 494 million bushels for 1980 and 621 million bushels for 1985. With a reserve stock of wheat of this average size, the probability of the market price for wheat holding within the defined price boundaries of plus or minus 10 percent of the target price is 84 percent in 1980 and 86 percent in 1985.

The consequences of a beginning reserve stock of 250 million bushels are explored in table 9. As in each earlier case, the effect of beginning stocks that are greater than zero is to reduce the price variability in the first year, 1975, but thereafter the effect of the beginning stocks diminishes.

If one accepts the assumed price elasticities of the model, the consequences of a price stabilization effort under the bounded price rule are clear. The annual variability in wheat prices around the target price are greatly reduced, but a significant degree of price variability remains even after the imposition of a plus or minus 10 percent formulation of the bounded price rule. Nonsymmetrical formulations of the bounded price rule were not analyzed in the U.S. wheat model as they were in the world model.

The consequences of applying the price variability minimization rule with zero beginning reserve stocks to the U.S. wheat model are explored in table 10. The variation in market prices around the target prices is reduced significantly by applying the specific formulation, infinite valuation of stability relative to costs, of the minimization rule. The average annual variation in market prices around the target prices is reduced to approximately 29 percent in 1975, 18 percent in 1980, and 21 percent in 1985 compared with 44 percent in 1975, 51 percent in 1980, and 56 percent in 1985 in the free market. The reduction in price variability under the infinite valuation of stability relative to costs formulation of the minimization rule is consistently greater over the years than the reduction achieved under the plus or minus 10 percent formulation of the bounded price rule (compare tables 10 and 8). Further, in the U.S. wheat model the average volume of reserve stocks accumulated under the infinite valuation of stability relative to costs formulation of the minimization rule is consistently larger over the years than in the plus or minus 10 percent formulation of the bounded price model (compare tables 10 and 8). This suggests that the marginal effort to reduce price instability below the level achieved by the bounded price rule, plus or minus 10 percent, is very expensive.

The consequences of having a beginning stock of 250 million bushels of wheat in the application of the price variability minimization rule are explored in table 11. Again the principal effects of the assumption of a positive beginning reserve stock are to be found in the 1st year. Price variability around the target price is reduced significantly in 1975 with the beginning stock assumption of 250 million bushels over what it was in 1975 with an assumption of zero beginning stocks. Again, after 1975 the effects of the beginning stock assumption are minimal. Average reserve stock accumulation remains large with the assumption of 250 million bushels of beginning stocks under the minimization rule relative to the bounded price rule (compare tables 11 and 9).

The experimentation with the minimization rule in the U.S. wheat market does not change the conclusion reached earlier in this section in connection with the bounded price rule. The application of either model to the free market situation significantly reduces the variation in market prices around the target prices; but even after undertaking intensive price stabilization efforts, an important degree of price variability remains in the U.S. wheat market.

The wheat market treated alone is an unruly market. This is caused by the large fluctuations in wheat production around the world, a relatively low price elasticity of demand for wheat, and the "cobweb" feature of the supply. We believe that a U.S. model that simultaneously includes all grains would exhibit greater price stability, before and after a stabilization effort, because total grains production around the world is much more stable than wheat production. And through the process of substitution on both the demand and supply sides the price of wheat would be pulled into line with the prices of the other grains. Thus, we again conclude that any stabilization effort for the grains should be undertaken for all grains and not for a single grain such as wheat. We believe that further research work with the U.S. model will substantiate this conclusion.

One final point should be made regarding the trend in target wheat prices and the average market wheat prices in tables 8-11. The authors do not believe that wheat prices are likely to trend downward from 1975 to 1985. But the extrapolation of past growth and market trends into the future brings that result. The fact that prices trend downward in this analysis is not, however, important to the analysis. We are concerned in this analysis with estimating fluctuation in market prices around trend and in dampening down those short-run price fluctuations through various kinds and forms of price stabilization programs. Thus, we made no effort to adjust future trends in wheat prices to take account of possible new production and market developments for wheat and other grains.

Table 1. Price stabilization results: All grains, world model with alternative bounded price rules, for selected years, 1975-1985, with the assumptions of a zero beginning reserve stock[1] and a price elasticity of demand of -.1[2]

Measure	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Plus 10%, minus 5% of the target price, 100		
	[5]	1975	1980	1985	1975	1980	1985	1975	1980	1985
Probability in percent of market price being[3]										
at or less than 50	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
at or less than 80	25.6	0.0	0.0	0.0	25.6	25.6	25.6	0.0	0.0	0.0
at or less than 90	38.7	38.7	38.7	38.7	38.7	38.7	38.7	0.0	0.0	0.0
at or less than 100	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0
at or less than 110	65.2	65.2*	81.2*	85.3*	65.2	65.2	65.2	65.2*	84.5*	88.8*
at or less than 120	77.7	77.7	89.1	91.6	77.7*	86.5*	89.3*	77.7	91.2	93.7
at or less than 150	97.9	97.9	99.2	99.4	97.9	99.0	99.3	97.9	99.4	99.6
Average market price	100	107	103	103	104	102	102	109	105	104
Av. variation around the target price in %	27.4	20.4	15.4	14.2	22.5	19.9	19.1	19.7	13.3	11.8
Probability of being out of stocks	–	65.2	29.9	22.9	76.1	36.5	27.5	59.3	22.8	16.1
Average reserve stock in million tons[4]	–	9.01	38.2	56.7	5.20	24.3	39.3	11.8	50.5	72.6
Average world production in million tons	–	1308	1513	1750	1308	1513	1750	1308	1513	1750
Percent stocks are of production	–	0.69	2.52	3.24	0.40	1.61	2.25	0.90	3.34	4.15
Coefficient of variation in stocks in % of the mean	–	176	105	88	222	118	102	156	101	73

[1] The assumption zero beginning reserve stocks does not mean "no stocks." We assume that working stocks for normal intra-year business operations are in being.

[2] The demand function is assumed to be linear, hence the elasticity of -.1 holds only at the mean.

[3] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[4] The actual reserve stock for any given year may be greater or less than the estimates presented on this line, because the estimates presented on this line are mean averages of possible stock quantities. Each level of reserve stocks has a probability. Those probabilities are not presented here; they are discussed in the technical section of this report.

[5] The free market price is 100 for every year from 1975 to 1985, because it is assumed that world demand and world supply grow at uniform and equal rates.

Table 2. Price stabilization results: All grains, world model with alternative bounded price rules for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 20 million tons[1] and a price elasticity of demand of -.1[2]

Measure	Free market[5]	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Plus 10%, minus 5% of the target price, 100		
		1975	1980	1985	1975	1980	1985	1975	1980	1985
Probability in percent of market price being[3]										
at or less than 50	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
at or less than 80	25.6	0.0	0.0	0.0	25.6	25.6	25.6	0.0	0.0	0.0
at or less than 90	38.7	38.7	38.7	38.7	38.7	38.7	38.7	0.0	0.0	0.0
at or less than 100	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0
at or less than 110	65.2	82.2*	83.6*	86.2*	65.2	65.2	65.2	82.2*	86.5*	89.6*
at or less than 120	77.7	91.1	90.6	92.1	91.1*	89.7*	90.5*	91.1	92.4	94.2
at or less than 150	97.9	100.0	99.4	99.5	100.0	99.4	99.4	100.0	99.5	99.6
Average market price	100	103	103	102	101	102	102	105	104	104
Av. variation around the target price in %	27.4	13.9	14.6	13.9	18.1	19.0	18.8	11.9	11.9	11.0
Probability of being out of stocks	–	22.3	25.8	21.5	13.2	25.9	23.8	22.3	19.7	15.0
Average reserve stock in million tons[4]	–	23.4	44.6	59.9	21.7	33.3	45.3	26.2	57.2	75.6
Average world production in million tons	–	1308	1513	1750	1308	1513	1750	1308	1513	1750
Percent stocks are of production	–	1.79	2.94	3.42	1.66	2.20	2.59	2.00	3.78	4.32
Coefficient of variation in stocks in % of the mean	–	88	97	85	69	100	95	89	84	71

[1] The assumption of beginning stocks of 20 million tons does not mean that this is the total of all stocks. We assume that working stocks for normal intra-year business operations are in being and in addition to the 20 million tons of beginning reserve stocks.

[2] The demand function is assumed to be linear, hence the elasticity of –.1 holds only at the mean.

[3] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[4] The actual reserve stock for any given year may be greater or less than the estimates presented on this line, because the estimates presented on this line are mean averages of possible stock quantities. Each level of reserve stocks has a probability. Those probabilities are not presented here; they are discussed in the technical section of this report.

[5] The free market price is 100 for every year from 1975 to 1985, because it is assumed that world demand and world supply grow at uniform and equal rates.

Table 3. Price stabilization results: All grains, world model with alternative bounded price rules for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 50 million tons[1] and a price elasticity of demand of -.1[2]

Measure	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Plus 10%, minus 5% of the target price, 100		
	[5]	1975	1980	1985	1975	1980	1985	1975	1980	1985
Probability in percent of market price being[3]										
at or less than 50	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0
at or less than 80	25.6	0.0	0.0	0.0	25.6	25.6	25.6	0.0	0.0	0.0
at or less than 90	38.7	38.7	38.7	38.7	38.7	38.7	38.7	0.0	0.0	0.0
at or less than 100	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0
at or less than 110	65.2	95.8*	88.3*	88.1*	65.2	65.2	65.2	95.8*	90.4*	91.1*
at or less than 120	77.7	100.0	93.5	93.3	100.0*	94.6*	93.2*	100.0	94.7	95.1
at or less than 150	97.9	100.0	99.6	99.6	100.0	99.7	99.6	100.0	99.7	99.7
Average market price	100	100	102	102	100	101	101	102	104	104
Av. variation around the target price in %	27.4	9.4	13.2	13.3	16.2	17.6	18.1	7.7	11.2	11.0
Probability of being out of stocks	–	4.2	18.1	18.3	1.3	12.5	16.5	4.2	13.8	12.7
Average reserve stock in million tons[4]	–	50.2	59.5	67.3	50.1	54.2	60.0	52.9	71.6	81.9
Average world production in million tons	–	1308	1513	1750	1308	1513	1750	1308	1513	1750
Percent stocks are of production	–	3.84	3.93	3.85	3.83	3.58	3.43	4.04	4.73	4.68
Coefficient of variation in stocks in % of the mean	–	50	81	78	36	73	79	53	71	65

[1] The assumption of beginning stocks of 50 million tons does not mean that this is the total of all stocks. We assume working stocks for normal intra-year business operations are in being and in addition to the 50 million beginning stocks.

[2] The demand function is assumed to be linear, hence the elasticity of –.1 holds only at the mean.

[3] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[4] The actual reserve stock for any given year may be greater or less than the estimates presented on this line, because the estimates presented on this line are mean averages of possible stock quantities. Each level of reserve stocks has a probability. Those probabilities are not presented here they are discussed in the technical section of this report.

[5] The free market price is 100 for every year from 1975 to 1985, because it is assumed that world demand and world supply grow at uniform and equal rates.

Table 4. Price stabilization results: All grains, world model with alternative bounded price rules and a limitation on stock accumulation[1] for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 20 million tons[2] and a price elasticity of demand of -.1[3]

Measure	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100		
	[6]	1975	1980	1985	1975	1980	1985
Probability in percent of market price being							
at or less than 50	4.2	0.0	1.4	1.5	0.0	1.2	1.3
at or less than 80	25.6	13.2	13.7	13.2	25.6	25.6	25.6
at or less than 90	38.7	38.7	38.7	38.7	38.7	38.7	38.7
at or less than 100	51.0	51.0	51.0	51.0	51.0	51.0	51.0
at or less than 110	65.2	82.2	79.1	78.6	65.2	65.2	65.2
at or less than 120	77.7	91.1	88.2	88.2	91.1	88.3	88.0
at or less than 150	97.9	100.0	99.2	99.2	100.0	99.3	99.3
Probability of market price falling within the bounded range[4]	–	64.4	59.2	59.4	80.1	76.8	77.5
Average market price	100	100	100	101	100	100	100
Av. variation around the target price in %	27.4	17.5	20.0	19.8	19.9	21.6	21.6
Probability of being out of stocks	–	22.3	32.5	32.3	13.2	28.9	29.9
Average reserve stock in million tons[5]	–	19.9	22.0	29.7	20.0	21.5	24.1
Average world production in million tons	–	1308	1513	1750	1308	1513	1750
Percent stocks are of production	–	1.52	1.45	1.41	1.53	1.42	1.38
Coefficient of variation in stocks in % of the mean	–	71	87	86	56	84	85

Reserve stock accumulation for the world is limited to 3 percent of total world grain production in each year.

The assumption of beginning stocks of 20 million tons does not mean that this is the total of all stocks. We assume that working stocks for normal intra-year business operations are in being and in addition to the 20 million beginning reserve stocks.

The demand function is assumed to be linear, hence the elasticity of -.1 holds only at the mean.

The probabilities of market price falling within the bounded price range differ in this exercise from the estimates presented opposite the price levels immediately above, hence they are presented here as separate estimates.

The actual reserve stock for any given year may be greater or less than the estimates presented on this line, because the estimates presented on this line are mean averages of possible stock quantities. Each level of reserve stocks has a probability. Those probabilities are not presented here; they are discussed in the technical section of this report.

The free market price is 100 for every year from 1975 to 1985, because it is assumed that world demand and world supply grow at uniform and equal rates.

Table 5. Price stabilization results: All grains, world model with alternative bounded price rules for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 20 million tons[1] and a price elasticity of demand of -.2[2]

Measure	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100		
	[5]	1975	1980	1985	1975	1980	1985
Probability in percent of market price being[3]							
at or less than 50	0.0	0.0	0.0	0.0	0.0	0.0	0.0
at or less than 80	8.9	0.0	0.0	0.0	8.9	8.9	8.9
at or less than 90	25.6	25.6	25.6	25.6	25.6	25.6	25.6
at or less than 100	51.0	51.0	51.0	51.0	51.0	51.0	51.0
at or less than 110	76.1	89.1*	88.5*	89.5*	76.1	76.1	76.1
at or less than 120	92.9	97.9	97.3	97.4	97.9*	97.6*	97.1*
at or less than 150	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average market price	100	101	101	101	100	100	100
Av. variation around the target price in %	13.7	9.1	9.6	9.4	12.5	12.6	12.6
Probability of being out of stocks	–	13.2	26.1	24.1	2.1	10.7	16.6
Average reserve stock in million tons[4]	–	21.6	33.1	45.1	20.1	21.3	23.2
Average world production in million tons	–	1308	1513	1750	1308	1513	1750
Percent stocks are of production	–	1.65	2.19	2.58	1.54	1.41	1.33
Coefficient of variation in stocks in % of the mean	–	69	100	95	28	66	82

[1] The assumption of beginning stocks of 20 million tons does not mean that this is the total of all stocks. We assume that working stocks for normal intra-year business operations are in being and in addition to the 20 million beginning reserve stocks.

[2] The demand function is assumed to be linear, hence the elasticity of –.2 holds only at the mean.

[3] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[4] The actual reserve stock for any given year may be greater or less than the estimates presented on this line, because the estimates presented on this line are mean averages of possible stock quantities. Each level of reserve stocks has a probability. Those probabilities are not presented here; they are discussed in the technical section of this report.

[5] The free market price is 100 for every year from 1975 to 1985, because it is assumed that world demand and world supply grow at uniform and equal rates.

Table 6. Price stabilization results: All grains, world model, price variability minimization rule,[1] for selected years, 1975-1985, with the assumptions of a zero beginning reserve stock[2] and a price elasticity of demand of −.1[3]

Measure	Free market	Valuation of stability relative to costs[4]											
		Infinite			High			Moderate			Low		
	[5]	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Probability in percent of market price being													
at or less than 50	4.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
at or less than 80	25.6	0.0	0.2	1.3	0.0	0.1	0.3	0.0	0.1	0.3	0.0	0.5	0.8
at or less than 90	38.7	0.0	1.5	5.3	0.0	3.3	6.0	0.0	7.0	8.6	6.0	20.6	23.6
at or less than 100	51.0	1.3	21.4	33.3	20.7	47.2	51.6	31.2	52.8	53.8	42.8	59.6	61.3
at or less than 110	65.2	53.1	78.2	81.4	65.2	81.1	81.8	65.2	79.6	80.0	65.2	76.6	76.5
at or less than 120	77.7	77.7	92.2	93.0	77.7	89.4	89.6	77.7	88.4	88.4	77.7	86.4	86.0
at or less than 150	97.9	97.7	99.6	99.6	97.9	99.4	99.4	97.9	99.3	99.3	97.9	99.1	99.0
Average market price	100	116	107	105	112.3	105.6	104.5	111	105	104	110	103	103
Av. variation around the target price in %	27.4	20.5	12.7	12.6	19.7	13.4	13.8	19.6	14.4	14.6	19.7	16.1	16.5
Probability of being out of stocks	–	32.9	13.2	12.0	38.7	20.5	21.9	40.7	25.2	25.1	44.8	34.0	35.0
Average reserve stock in million tons	–	16.5	46.7	62.0	13.3	33.4	38.4	12.1	26.3	31.9	10.3	18.9	21.2
Average world production in million tons	–	1308	1513	1750	1308	1513	1750	1308	1513	1750	1308	1513	1750
Percent stocks are of production	–	1.26	4.22	3.54	1.00	2.21	2.19	.93	1.74	1.82	.79	1.25	1.21
Coefficient of variation in stocks in % of the mean	–	106	90	87	116	101	106	121	106	111	127	113	120

[1] The rule is framed to minimize price variability around the target price for the entire period under consideration, 1975-1985.

[2] The assumption of zero beginning reserve stocks does not mean "no stocks." We assume that working stocks for normal intra-year business operations are in being.

[3] The demand function is assumed to be linear, hence the elasticity of −.1 holds only at the mean.

[4] Valuation of stability relative to costs is measured by an index that we call λ. This λ is discussed in the text, but basically λ represents the willingness of society to accept program costs to achieve price stabilization objectives.

[5] The values indicated for the free market situation hold for 1975 and every other year from 1975 to 1985.

Table 7. Price stabilization results: All grains, world model, price variability minimization rule[1] for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 20 million tons.[2] with a price elasticity of demand of -.1[3]

Measure	Free market	Valuation of stability relative to costs[4]											
		Infinite			High			Moderate			Low		
	[5]	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Probability in percent of market price being													
at or less than 50	4.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
at or less than 80	25.6	0.0	0.3	1.3	0.0	0.1	0.4	0.0	0.1	0.3	0.0	0.5	0.8
at or less than 90	38.7	0.0	1.9	5.4	0.0	3.6	6.1	0.8	7.4	8.6	14.6	20.9	23.6
at or less than 100	51.0	5.0	22.6	33.6	38.9	47.8	51.7	47.0	53.3	53.8	55.2	59.8	61.3
at or less than 110	65.2	65.2	78.8	81.6	77.7	81.4	81.9	77.7	79.8	80.0	77.7	76.8	76.5
at or less than 120	77.7	86.8	92.5	93.1	86.8	89.6	89.6	86.8	88.6	88.4	86.8	86.5	86.0
at or less than 150	97.9	100.0	99.6	99.6	100.0	99.4	99.4	100.0	99.3	99.3	100.0	99.1	99.0
Average market price	100	111	107	105	107	105	104	106	104	104	103	103	103
Av. variation around the target price in %	27.4	15.2	12.5	12.6	14.2	13.6	13.8	14.1	14.3	14.6	14.7	16.1	16.5
Probability of being out of stocks	–	17.8	12.8	11.9	22.3	21.5	21.9	25.6	24.9	25.1	32.9	33.8	35.0
Average reserve stock in million tons	–	24.4	48.3	62.6	20.3	31.4	38.6	19.0	26.8	32.0	16.1	19.1	21.2
Average world production in million tons	–	1308	1513	1750	1308	1513	1750	1308	1513	1750	1308	1513	1750
Percent stocks are of production	–	1.87	3.19	3.58	1.50	1.94	2.20	1.45	1.77	1.83	1.23	1.26	1.21
Coefficient of variation in stocks in % of the mean	–	83	90	87	91	103	106	95	106	111	102	113	120

[1] The rule is framed to minimize price variability around the target price for the entire period under consideration, 1975-1985.

[2] The assumption of beginning stocks of 20 million tons does not mean that this is the total of all stocks. We assume that working stocks for normal intra-year business operations are in being and in addition to the 20 million tons of beginning reserve stocks.

[3] The demand function is assumed to be linear, hence the elasticity of –.1 holds only at the mean.

[4] Valuation of stability relative to costs is measured by an index that we call λ. This λ is discussed in the text, but basically λ represents the willingness of society to accept program costs to achieve price stabilization objectives.

[5] The values indicated for the free market situation hold for 1975 and avery other year from 1975 to 1985.

Table 8. Price stabilization results: Wheat, United States model, with alternative bounded price rules, for selected years, 1975-1985, with the assumptions of a zero beginning reserve stock[1] and a price elasticity of demand of approximately -.43[2]

Measure	Free market equilibrium price			Plus or minus 10% of the target price			Plus or minus 20% of the target price		
	$3.47 in 1975	$3.18 in 1980	$2.90 in 1985	$3.47 in 1975	$3.18 in 1980	$2.90 in 1985	$3.47 in 1975	$3.18 in 1980	$2.90 in 1985
Probability in percent of market price being[3]									
at or less than 50% of T.P.	23	23	27	0	0	0	0	0	0
at or less than 80% of T.P.	44	39	41	0	0	0	44	38	41
at or less than 90% of T.P.	52	44	46	52	47	46	52	46	46
at or less than 100% of T.P.	60	51	51	60	54	53	60	53	53
at or less than 110% of T.P.	68	57	57	68*	84*	86*	68	61	59
at or less than 120% of T.P.	74	63	62	74	87	89	74*	84*	86*
at or less than 150% of T.P.	92	81	78	92	96	96	92	95	94
Average market price	3.12	3.23	2.99	3.74	3.33	3.02	3.60	3.27	3.01
Av. variation around the target price in %	44.1	51.2	56.1	27.5	20.2	21.6	30.2	26.9	28.2
Probability of being out of stocks				52.0	20.0	17.0	60.0	24.0	20.0
Average reserve stock in million bushels				146.4	493.9	620.9	114.7	363.2	494.7
Average U.S. production in million bushels				2216	2455	2829	2216	2452	2825
Percent stocks are of U.S. production				6.6	20.1	22.0	5.2	14.8	17.5
Coefficient of variation in stocks in % of the mean				128	85	76	147	92	85

The assumption of zero beginning reserve stocks does not mean "no stocks." We assume that working stocks for normal intra-year business operations are in being.

In this exercise we assume a price elasticity of demand for the U.S. market for wheat of -.43 for 1975, of which the domestic price elasticity is assumed to be -.378 and the export price elasticity is assumed to be -.5. Over the period 1975-1985, the total market price elasticity increases somewhat as the export share of the market increases.

The starred probabilities give the probability of market price falling within the particular bounded price objective.

Table 9. Price stabilization results: Wheat, United States model with alternative bounded price rules for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 250 million bushels[1] and a price elasticity of demand of approximately -.43[2]

Measure	Free market equilibrium price			Plus or minus 10% of the target price			Plus or minus 20% of the target price		
	$3.47 in 1975	$3.18 in 1980	$2.90 in 1985	$3.47 in 1975	$3.18 in 1980	$2.90 in 1985	$3.47 in 1975	$3.18 in 1980	$2.90 in 1985
Probability in percent of market price being[3]									
at or less than 50% of T.P.	23	23	27	0	0	0	0	0	0
at or less than 80% of T.P.	44	39	41	0	0	0	33	39	41
at or less than 90% of T.P.	52	44	46	53	29	46	53	46	46
at or less than 100% of T.P.	60	51	51	60	53	53	60	53	53
at or less than 110% of T.P.	68	57	57	84*	85*	84*	68	60	59
at or less than 120% of T.P.	74	63	62	90	89	89	85*	87*	82*
at or less than 150% of T.P.	92	81	78	100	96	96	100	96	94
Average market price	3.12	3.23	2.99	3.50	3.32	3.02	3.42	3.25	3.00
Av. variation around the target price in %	44.1	51.2	56.1	15.9	19.7	20.8	20.7	25.4	26.8
Probability of being out of stocks				18.7	17.8	16.4	12.3	19.4	18.3
Average reserve stock in million bushels				339.7	557.5	641.4	318.0	447.0	537.3
Average production in million bushels				2216	2452	2828	2216	2447	2823
Percent stocks are of U.S. production				15.3	22.7	22.7	14.4	18.3	19.0
Coefficient of variation in stocks in % of the mean				77	80	74	68	85	82

[1] The assumption of beginning stocks of 250 million bushels does not mean that this is the total of all stocks. We assume that working stocks for normal intra-year business operations are in being and in addition to the 250 million bushels of beginning reserve stocks.

[2] In this exercise we assume a price elasticity of demand for the U.S. market for wheat of -.43 for 1975, of which the domestic price elasticity is assumed to be -.378 and the export price elasticity is assumed to be -.5. Over the period 1975-1985, the total market price elasticity increases somewhat as the export share of the market increases.

[3] The starred probabilities give the probability of market price falling within the particular bounded price objective.

Table 10. Price stabilization results: Wheat, United States model, price variability minimization rule,[1] for selected years, 1975-1985, with the assumptions of a zero beginning reserve stock[2] and a price elasticity of demand of approximately -.43[3]

Measure	Free market			Valuation of stability relative to costs[4]											
				Infinite			High			Moderate			Low		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Target price	$3.47	$3.18	$2.90	$3.47	$3.18	$2.90	$3.47	$3.18	$2.90	$3.47	$3.18	$2.90	$3.47	$3.18	$2.90
Probability in percent of market price being															
at or less than 50% of T.P.	23	23	27	0	1	2	0	0	0	0	0	1	0	2	2
at or less than 80% of T.P.	44	39	41	0	7	9	16	19	15	28	30	31	40	42	38
at or less than 90% of T.P.	52	44	46	0	19	22	36	42	37	48	47	45	52	52	50
at or less than 100% of T.P.	60	51	51	12	45	47	51	63	57	60	64	60	60	59	58
at or less than 110% of T.P.	68	57	57	48	79	77	68	78	76	68	71	71	68	65	64
at or less than 120% of T.P.	74	63	62	72	93	91	74	82	83	74	76	76	74	70	69
at or less than 150% of T.P.	92	81	78	92	98	98	92	94	93	92	91	89	92	87	85
Average market price	3.12	3.23	2.99	4.12	3.28	2.98	3.76	3.22	3.00	3.59	3.23	3.01	3.41	3.21	3.03
Av. variation around the target price in %	44.1	51.2	56.1	29.1	17.7	20.7	28.9	25.5	27.8	31.1	31.2	34.2	34.9	37.9	41.3
Probability of being out of stocks				28.0	6.0	5.0	40.0	26.0	23.0	44.0	41.0	35.0	56.0	56.0	51.0
Average reserve stock in million bushels				246.4	688.5	750.5	156.8	276.8	334.4	115.7	162.8	202.0	71.1	82.5	105.6
Average U.S. production in million bushels				2216	2451	2813	2216	2439	2814	2216	2437	2816	2216	2440	2807
Percent stocks are of U.S. production				11.1	28.1	26.7	7.1	11.3	11.9	5.2	6.7	7.2	3.2	3.4	3.8
Coefficient of variation in stocks in % of the mean				90	58	55	106	91	86	115	110	101	135	137	126

[1] The rule is framed to minimize price variability around the target price for the entire period under consideration, 1975-1985.

[2] The assumption zero beginning reserve stocks does not mean "no stocks." We assume that working stocks for normal intra-year business operations are in being.

[3] In this exercise we assume a price elasticity of demand for the U.S. market for wheat of −.43 for 1975, of which the domestic price elasticity is assumed to be −.378 and the export price elasticity is assumed to be −.5. Over the period 1975-1985, the total market price elasticity increases somewhat as the export share of the market increases.

[4] Valuation of instability relative to costs is measured by an index that we call λ. This λ is discussed in the text, but basically λ represents the willingness of society to accept program costs to achieve price stabilization objectives.

Table 11. Price stabilization results: Wheat, United States model, price variability minimization rule,[1] for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 250 million bushels[2] and a price elasticity of demand of approximately -.43[3]

Measure	Free market			Valuation of stability relative to costs[4]											
				Infinite			High			Moderate			Low		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Target price	$3.47	$3.18	$2.90	$3.47	$3.18	$2.90	$3.47	$3.18	$2.90	$3.47	$3.18	$2.90	$3.47	$3.18	$2.90
Probability in percent of market price being															
at or less than 50% of T.P.	23	23	27	0	1	2	0	0	0	0	0	1	0	2	2
at or less than 80% of T.P.	44	39	41	0	7	10	0	18	15	47	29	33	66	42	39
at or less than 90% of T.P.	52	44	46	3	20	23	22	42	38	66	47	46	72	52	50
at or less than 100% of T.P.	60	51	51	34	46	47	40	63	57	78	64	60	78	58	58
at or less than 110% of T.P.	68	57	57	72	80	76	59	78	76	84	71	71	84	65	64
at or less than 120% of T.P.	74	63	62	88	94	90	72	83	82	90	76	76	90	71	69
at or less than 150% of T.P.	92	81	78	100	98	98	92	94	93	100	91	89	100	87	83
Average market price	3.12	3.23	2.99	3.76	3.26	2.98	3.29	3.22	3.00	3.04	3.23	3.01	2.73	3.21	3.03
Av. variation around the target price in %	44.1	51.2	56.1	16.5	17.6	19.9	19.3	25.5	27.0	25.2	31.2	33.3	34.6	37.9	40.2
Probability of being out of stocks				12.3	5.74	4.84	18.7	26.0	23.5	24.9	41.1	35.3	35.8	56.2	51.3
Average reserve stock in million bushels				408.7	702.5	751.3	290.1	278.0	334.4	227.0	162.9	202.0	149.8	82.4	105.6
Average U.S. production in million bushels				2216	2446	2817	2216	2438	2814	2216	2437	2816	2216	2440	2807
Percent stocks are of U.S. production				18.4	28.7	26.7	13.1	11.4	11.9	10.2	6.7	7.2	6.8	3.4	3.8
Coefficient of variation in stocks in % of the mean				67	57	55	77	91	86	85	109	101	100	137	126

[1] The rule is framed to minimize price variability around the target price for the entire period under consideration, 1975-1985.

[2] The assumption of beginning stocks of 250 million bushels does not mean that this is the total of all stocks. We assume that working stocks for normal intra-year business operations are in being and in addition to the 250 million bushels of beginning reserve stocks.

[3] In this exercise we assume a price elasticity of demand for the U.S. market for wheat of -.43 for 1975, of which the domestic price elasticity is assumed to be -.378 and the export price elasticity is assumed to be -.5. Over the period 1975-1985, the total market price elasticity increases somewhat as the export share of the market increases.

[4] Valuation of instability relative to costs is measured by an index that we call λ. This λ is discussed in the text, but basically λ represents the willingness of society to accept program costs to achieve price stabilization objectives.

PART VI. SOME POLICY AND ORGANIZATIONAL ISSUES

It is not the purpose of this study to recommend either for or against an international reserve stock program with the objective of price stabilization. That being the case, we do not in this study make any recommendation about specific reserve stock decision rules. But we believe that the kind of information developed and presented in this study will prove helpful to policymakers in the concerned countries as to whether or not to embark upon reserve stock programs that seek to achieve international price stabilization for the grains. Indeed, this kind of information is essential to rational decisionmaking in this stabilization area. But policy and organizational issues exist that bear upon the question of international price stabilization for the grains that should be recognized and understood. We will explore some of those issues in this part.

But first we should like to make two points about the functioning of an international reserve stock program for the grains that are not always fully appreciated. First, grain prices would be allowed to vary under the operation of a reserve stock program of the type envisaged in this study, and thus perform their proper resource allocation role. But the extreme and disruptive amplitude of those price variations would be dampened down by the operation of the reserve stock program. Second, in the functioning of the world grain market, the stabilization objectives and stock decision rules would be known to all individuals, firms, and governments operating in that market. Hence, all operators would know what to expect with regard to the future behavior of that market. The international grain market would become a more "fair game" in that all players would be playing under the same and known set of rules. The impact of a reserve stock program of the kind envisaged here on the international grain market would not be to weaken or destroy it. On the contrary, the market should be strengthened as it became increasingly stable and predictably more certain.

If the world market for grains were a free market in which there were no barriers to trade, then an international reserve stock program could operate most effectively and efficiently under a single international agency in which the reserve stocks were held in the surplus producing areas and were released to the deficit areas as needed. But the world market is not one large free market; further, the world market is fraught with uncertainty. This means that the countries most concerned with the maintenance of adequate domestic supplies and stable domestic prices will want those reserve stocks stored in, or readily available to, their respective countries. This suggests that if any international reserve stock program comes into being, it will be developed by the countries most concerned through some form of international agreement. In such an arrangement it seems likely that the management of each country's reserve stock would be undertaken by the country involved, but some form of coordinated or concerted action would be attempted. Further, we would expect that the concerned countries entering into such an arrangement might include both importers and exporters of grains, but for somewhat different reasons. The exporters might include Australia, Canada, Thailand, and the United States; the importers might include various European countries, Japan, and the city states such as Hong Kong and Singapore. In the long run the Soviet Union might find it to its advantage to enter into such an international stabilization arrangement, but recent history suggests that the Soviets would for a time at least rely upon imperfect information and chaotic conditions in the international grain markets to work to their advantage.

Given this kind of international organizational arrangement, the policy point that we wish to make is the following. For the arrangement to be effective, an agreement must be made first about the stabilization target price, or target price range, and second about the rules for acquiring and releasing stocks. If complete agreement does not exist by the country participants to the international arrangement on these points, the arrangement would meet with "rough sailing" and probably failure. Imagine what would happen if one country or group of countries sought to stabilize prices at a lower level than that of some other countries. The first group of countries would be continuously, or to the extent possible, releasing stocks to drive prices down, while the second group would be required to acquire unnecessarily large stocks to hold prices up to its price stabilization targets. The international stabilization effort would be working at cross purposes and would become an exercise in frustration and failure.

There are other program issues upon which agreement would have to be reached by the participating nations if the international stabilization program were to operate successfully. These issues include agreement on:

1. the maximum total stock to be acquired at any point in time,
2. the shares of that maximum to be held by each country participant, and
3. some means for coordinating stock acquisition and disposition actions by countries so that changes in stock positions in countries were deemed by the participants to be fair and equitable.

In sum, an international effort to stabilize grain prices through the operation of reserve stock programs in individual participating countries would require a high degree of coordination through an international secretariat to make the program operate smoothly and equitably.

The achievement of agreement on stabilization target prices and stocking rules is complicated by the fact that producer interests, which seek relatively high target prices, will in some participating countries be predominant, while in other countries consumer interests, which seek relatively low target prices, will be predominant. In still other countries, such as the United States, for example, the producer and consumer interests may be sufficiently evenly matched to make reaching an agreement within the country on a stabilization target price extremely difficult if not impossible.

This problem of reaching an agreement on the level of target price in a country such as the United States *may be* further complicated by the recent theory that the demand for grains has in recent years become more inelastic at high prices and more elastic at lower prices, wherein consumers have more to gain and producers more to lose from price stabilization than formerly was the case.[11] Whether this

[11] See the FAO document prepared by Jimmye Hillman, D. Gale Johnson, and Roger Gray, *Food Reserve Policies for World Food Security: A Consultant's Study on Alternative Approaches*, ESC: CSP/75/2, January 1975, pp. 6-12 (a background document for the Expert Consultation on Cereal Stock Policies Relating to World Food Security, Rome, Italy, February 24-28, 1975).

theoretical argument will be supported by empirical evidence remains to be seen. But if it is, the difficulty of reaching agreement on the level of grain target prices will be increased within a country such as the United States and among exporter and importer countries in an international agreement unless satisfactory ways are found for the consumer interests to compensate the producer interests in an international stabilization effort. In other words, given the argument that the demand for grain has become increasingly inelastic at high prices and increasingly elastic at low prices, consumer interests around the world may be forced to accept higher price stabilization targets than they currently anticipate or make some form of compensatory payments to producers to bring the producer interests into an international reserve stock program to stabilize world grain prices.

On the other hand, the configuration of the demand curve may not be changing as hypothesized above, the world could experience a series of bountiful harvests and a return to a surplus condition, and the fixed cost phenomenon in farming could squeeze the net incomes of grain producers to the point where they would be happy to participate in an international stabilization effort at a relatively low target price. But in this latter situation, would consumers have any strong interest in price stabilization? Probably not. Thus, we observe that at any point in time, there is not likely to be a unity of interest about an international reserve stock program for the grains. The producer-consumer dichotomy of interests is a powerful one.

If the consumer-producer conflicts over price stabilization for the grains within countries and among countries are so severe that they preclude the implementation of an international reserve stock program for the grains - what then? One option open to the United States, if it is able to resolve its own consumer-producer conflict over price stabilization, would be the implementation of a reserve stock program sufficiently large to stabilize world grain prices. This option is not out of the question, even though the full costs would be borne by the United States (or all the profits flow into the United States, because a certain combination of events could result in the reserve stock program earning a net profit). The average size of the reserve stock, as suggested by this analysis, would be smaller than the total stock of grain held by the United States in the late 1950's and early 1960's in connection with its farm price support programs, which incidentally served to stabilize world prices. We are not recommending this policy option, but it is a realistic option if the United States were determined to stabilize its own domestic grain, hence food, price level and still be integrated into the world grain market.

But for reasons of national pride and diplomatic strategy it seems unlikely that the United States will pursue the course of action outlined above. What are the next points for consideration? First, the United States is not likely to withdraw from the international grain market; it needs that market to move its great surplus of grain and to earn foreign exchange. Second, there is no reason to believe that world grain price fluctuations will dampen down of their own accord over the next decade. In fact, there are two reasons why the amplitude of those fluctuations could increase: (1) the increased but sporadic entry of the two great state trading nations, the Soviet Union and the People's Republic of China, into the world market, and (2) the changing climate in the northern hemisphere and the possibility of increased variability in crop growing conditions associated with the changing climate. Third, there is no evidence to suggest that, and there is no logical reason why, private traders will increase their holdings of grain stocks in the future to moderate wide and unpredictable price fluctuations associated with unpredictable variations in world crop production and the trading policies of the state trading nations.

The logical argument in support of this last point follows:

> "... the profit motive will guide grain into consumption or storage according to facts presently known, beyond which the most probable will be assumed - meaning normal or average production. It amounts to a contradiction in terms to ask the marketplace to dictate stocks accumulation according to the lesser probability of some future crop failure. To be sure, some participants may premise the purchase of futures contracts upon the chance that crops not yet planted will fail, but likewise others will sell in anticipation of bumper crops. Unless market psychology is persistently biased on the pessimistic or optimistic side of matters, the market must reflect the known and most probable. There are no profits to be earned by consistently investing in improbable prospects - and crop failures, lacking regularity and predictability as they do, are not commercial propositions until such time as information becomes available to diminish the high probability of an average crop. If crop yields are taken to be stochastic (after due allowance for trends and control measures) then the most profitable assumption is that yields in any future year will be normal."[12]

Thus, in our view, world grain price variability seems likely to be as great, or greater, in the next decade than it was in the last. The problem of price instability in the grains, with the appropriate lags in animal product prices, is not going away by itself, nor will it be wished away. In this context what are the policy prospects in the United States? *They are more of the same.* In periods of sharply rising farm and food prices, policy actions in the United States are likely to include:

1. the imposition of ceiling prices on food products,
2. the further expansion of food programs to assist the poor (e.g., the food stamp plan),
3. the use of export limitations of both formal and informal types, and
4. sporadic attacks on the monopolistic practices of big business and big labor in the food industries.

In periods of falling farm prices and stable to declining food prices, policy actions in the United States are likely to include:

1. efforts to maintain or raise commodity loan rates,
2. the imposition of production controls,
3. the expansion of foreign food aid programs, and
4. the making of supplemental income payments to medium and small sized commercial farmers.

---

[12] *Food Reserve Policies for World Food Security: A Consultant's Study on Alternative Approaches, ibid.*, pp. 1-2.

The basic policy issue confronting consumers and producers of grain products specifically, and food products in general, in the United States may be formulated as follows. Are those interests content to leave the world grain price instability problem untouched and deal with its domestic symptoms in the future in essentially the same ways as they have been doing in the past 10 years? Or do they wish to initiate an international grain reserve program with the capacity to effect some reasonable stability in international grain prices and thus reduce the pressure to implement countervailing, or compensating, domestic programs? This is the basic policy issue confronting consumers and producers of food in the United States in the foreseeable future.

PART VII. TECHNICAL DISCUSSION OF COMPUTATIONAL PROCEDURES

The discussion in this part is designed for technicians interested in reviewing the procedures employed in this study for deriving empirical estimates. It should be useful also to those technicians who might be interested in developing further the reserve stock ideas and estimates presented in this study. A program was composed to compute the price variability minimization stocks rule for price stabilization. The program also computes the probability distributions of prices and stocks that result from applying different stocks rules. The computational procedures are explained in this part. A detailed flow chart of computation is presented in Appendix B.

Computation of the price variability minimization stocks rule. -- Any continuous variable (e.g., price, stocks, random disturbance) is approximated by dividing its domain into a series of discrete points. A correspondence between these points and the integers is then defined. For example, suppose that the domain of stocks is from 0 to 1000 (i.e., the probability of being less than 0 or greater than 1000 is zero) and that the approximation is made by using intervals of 100 between any two points. Then it is assumed that stocks can take on values of 0, 100, 200, . . ., 1000, and the correspondence between stocks and integer index is defined as follows:

CC(IC)	INDEXC(C)
0	1
100	2
200	3
.	.
.	.
.	.
1000	11

where CC(IC) is the quantity of stocks corresp nding to the index IC(IC=1, 2, . . .) and INDEXC(C) is the integer index corresponding to a stocks quantity of C. By making the division finer, one can approximate the variable under discussion as close as he wants to, but, of course, computation cost increases.

Following the approximation by discrete points, all continuous probability distributions are approximated by discrete probability distributions so that instead of density functions there are probability-mass functions.

Before proceeding to the computations let us explain the notations in this part. Following the notation of computer programs, no superscripts or subscripts are used. Names of integer variables begin with letters I through N. The name of the first index of an integer variable always begins with M and the last one with N. For example, the index of a period is denoted by IT, the first period is denoted by MT, and the last one by NT. Some of the notations used in this part are summarized in table 12.

Table 12. Notation Used in Part VII

Variable	Symbol	Corresponding integer variable		
		Name	First	Last
Current price	P	IP	1	NP
Lagged price	P1	IP1	1	NP
Market price	PP	IPP	1	NP
Carryover stocks	C	IC	1	NC
Beginning stocks (stocks from previous period)	C1	IC1	1	NC
Target price	PSTAR			
Time index		IT	MT	NT
Random disturbance	E	IE	1	NE
Unit storage cost	THETA			
Discount rate	DELTA			
Marginal substitution of instability for cost	LAMBDA			

The correspondence between the values of a variable and the integers enables us to express some of the functions in the system as functions of integer indices. For example, the stocks rule is a function of the market price and the beginning stocks and can be translated to a function of integer indices, say

$$C(IPP, IC1, IT) \equiv C[P(IPP), CC(IC1), IT] \quad \begin{array}{l} IC1 = 1, 2, \ldots, NC \\ IPP = 1, 2, \ldots, NP \end{array}$$

where P(IPP) and CC(IC1) are the price and stocks corresponding to the integers IPP and IC1 respectively and IT is the time index.

The computation procedure is basically a dynamic programming one. A summary of the problem follows. A planning period is divided into subperiods t=1, 2, ..., T. In each period the free market price (P_t) is determined by the price of the last period (P_{t-1}) and by a stochastic disturbance ϵ_t which has a known probability distribution. The final price of period t, (P_t), is determined by the free market price (P_t) and by the change of stocks ($\Delta C_t \equiv C_t - C_{t-1}$). The problem is to find stocks rules $[C_t(C_{t-1}, P_t)]$ as functions of the beginning stocks (C_{t-1}) and of the market price (P_t) which minimize

$$E\left\{\sum_{t=1}^{T}\left[\left(\frac{P_t - P_t^*}{P_t^*}\right)^2 \cdot \lambda + \theta \cdot C_t\right] \cdot \frac{1}{(1+\delta)^t}\right\}$$

where P_t^* is a target price for period t
θ is a unit storage cost per period
λ is a weight that defines a desired marginal substitution rate between instability and cost
δ is a discount rate
and E stands for the expectation operation.

Following the demand and supply model (see part III), the following two functions are defined in the program:

(a) The free market price (PP) at some period IT as a function of the disturbance (E) and the price of the previous period (P1). This function will be denoted by

PPFEP1(E, P1, IT).

(b) The final price (P) at some period IT, as a function of the free market price (PP) and the change of stocks (DC). This function will be denoted by

PFPPDC(PP, DC, IT).

The planning period in the present notation is from MT to NT (see table 12). The computation starts with the last period (NT) of the planning period. For each pair of indices IC1, IPP, corresponding to beginning stocks (C1) and market price (PP), respectively, the program finds the carryover C(IC1, IPP, NT) that minimizes the objective function for period NT [i.e., the instability index for period NT, weighted by LAMBDA, plus carryover cost (THETA times C)]. Basically, for a given pair (IC1, IPP), the program runs over all the indices IC = 1, 2, ..., NC (that correspond to different values of carryover). For each of them it computes:

(a) The change of stocks

DC = CC(IC) - CC(IC1)

where CC(I) is the quantity of stocks corresponding to I (I = IC or IC1 respectively).

(b) The price

PFPPDC[P(IPP), DC, NT]

where P(I) is the price corresponding to the integer index I (I = IPP for the market price PP).

(c) The value of the objective function for period NT, i.e.,

$$\left[\frac{\text{PFPPDC} - \text{PSTAR}}{\text{PSTAR}}\right]^2 * \text{LAMBDA} + \text{C(IC)} * \text{THETA}$$

where PSTAR is the target price.

The program then picks up the level of carryover for which the last expression is minimal. This level of carryover is stored in an array denoted by C(IC1, IPP, NT).

The minimum value of the objective function for period NT, given CC(IC1) and P(IPP), is also stored in an array denoted by V(IC1, IPP).

Recall that the market price (PP) is a function of the lagged price (P1) and the disturbance (E). The next step is to compute the expectation of V over E. This is done as follows: For any given value of the integer index IP1(IP1 = 1, 2, ..., NP) (corresponding to a lagged price P1) and IC1 (corresponding to a beginning stocks C1), the program runs over all the indices IE and computes:

(a) The market price PP

PP = PPFEP1[E(IE), P(IP1), NT]

where E(IE) is the disturbance corresponding to the integer index IE and P(IP1) is the price corresponding to IP1.

(b) IPP = INDEXP(PP)

where INDEXP is a function that transforms prices into their corresponding integer indices.

(c) V(IC1, IPP)*PROBE(IE)

where PROBE(IE) is the probability of the disturbance E(IE).

Finally the program sums all the last expressions for IE = 1, 2, ..., NE. Obviously, the expected value of V is a function of the beginning stocks C1 and the lagged price P1 (or their corresponding integer indices IC1, IP1), and it is stored in an array denoted by

EV(IC1, IP1), (IC1 = 1, 2, ..., NC. IP1 = 1, 2, ..., NP).

It is possible now to compute the minimization stocks rule for period NT-1 by a similar procedure. Given any pair IC1, IPP (now standing for beginning stocks and market price of period NT-1 instead of NT), run over all indices IC = 1, 2, ..., NC (now standing for carryover of NT-1) and find the one for which the objective function for the period (NT-1, NT) is minimized. This is done similarly to period NT as follows:

For each IC compute:

(a) The change of stocks

DC = CC(IC) - CC(IC1)

(b) The price

PFPPDC[P(IPP), DC, NT-1]

and its corresponding integer index

IP = INDEXP(PFPPDC)

(c) The value of the objective function for the period NT-1, NT

$$\left[\frac{\text{PFPPDC} - \text{PSTAR}}{\text{PSTAR}}\right]^2 * \text{LAMBDA} + \text{C(IC)} * \text{THETA} + \frac{1}{1 + \text{DELTA}} * \text{EV(IC, IP)}.$$

Then the program picks up the carryover for which the last expression is minimal and stores it in C(IC1, IPP, NT-1). The minimal value V(IC1, IPP) for (NT-1, NT) replaces the V(IC1, IPP) for NT in the same array. The only difference between NT-1 and NT is that in the latter the objective function does not include EV as it does for the first.

Next, the EV(IC, IP) for (NT-1, NT) is computed exactly as it was computed for NT and the program is ready to compute the optimal rule for NT-2 which is done exactly as for NT-1 but with a different time index. Period by period it proceeds from NT down to the first period of planning (i.e., MT).

For the computation of the minimization stocks rules, the only information that must be carried from period to period of computation is the expected value EV of the last period of computation. Hence much memory space is saved. However, the program also stores the stocks rules C(IC1, IPP, IT) of all the periods for the computation of probabilities. These computations are described later in this part. Before going through the probability computations, let us describe another stocks rule that was analyzed, namely a bounded price rule, in addition to the minimization stocks rule described above.

The bounded price rule. – This rule refers to some proposals for price stabilization that have a common feature of considering only price signals as indicators for reserve stocks activity. The level of beginning stocks enters the bounded price rule only in a primitive way; i.e., negative stocks are not feasible, so the minimal carryover is zero.

The rule is: Define a range of prices with a lower and an upper boundary. If the price should fall below the lower boundary the rule says to acquire stocks in the quantity that will push the price back up to the lower boundary. If the price is within the range, do not sell or buy anything. Finally, if the price should rise above the upper boundary, sell that quantity of stocks that will drive the price down to the lower boundary. If there are not enough stocks to achieve this, then the upper price boundary cannot be maintained.

Figure 1 is a flow chart of the bounded price rule. In this flow chart the boundaries are defined as percentages of target prices [PSTAR(IT)]. B1 and B2 are the percentages of the lower boundary and the upper boundary respectively. PSTAR1 and PSTAR2 are the boundaries and IPSTR1, IPSTR2 their corresponding integer indices. DC is the required change of stocks and BND(PSTARJ, PP, IT) is a function that defines the change of stocks needed when the market price is PP to change it to PSTARJ. As before, C(IC1, IPP, IT) is the stocks rule.

Probability computations of prices and stocks. – The most important information for the study of the implications of any stocks rule in the context of price stabilization is embodied in the probability distribution of prices and stocks under the application of the rule. In this section the program of probability computation is described. More details can be found in the flow chart in Appendix B.

To this part of the program, the stocks rule is given exogenously. Actually two rules were examined: (a) the minimization stocks rule and (b) the bounded price rule, both discussed in this part. The central computation of this part of the program is the computation of the joint probability distribution of stocks and prices in any period IT. Let us, therefore, begin with this. The marginal and cumulative probabilities, as well as some instability indices, will be described later.

Joint probability distribution of prices and stocks. – Recall that according to the approximative procedure, price may obtain only values of

$$P(IP) \quad IP = 1, 2, ..., NP,$$

and stocks may obtain only values of

$$CC(IC) \quad IC = 1, 2, ..., NC.$$

The joint probability of stocks and prices in period IT is denoted by PRBCP(IT, IC, IP).

$$PRBCP(IT, IC, IP) \equiv \text{Probability } [\text{stocks} = CC(IC), \text{Price} = P(IP)].$$

Two stochastic elements are involved in the computation of PRBCP(IT, IC, IP), namely:

(a) The joint probabilities of stocks and prices of the previous period (IT-1),

i.e., PRBCP(IT-1, IC1, IP1) IC1 = 1, 2, ..., NC
IP1 = 1, 2, ..., NP

(b) The probabilities of the stochastic disturbance of period IT, denoted by

$$PRBE(IE) \quad IE = 1, 2, ..., NE$$

The assumptions of the model imply that (a) and (b) are mutually independent. It follows that the probability of the combination of indices (IC1, IP1, IE) equals the product

$$PRBCP(IT-1, IC1, IP1) * PRBE(IE).$$

The following steps also are determined by the same combination of beginning stocks, lagged price, and current disturbance:

(a) P(IP1) and E(IE) determine the market price (PP) by the function PPFEP1(E, P1, IT):

$$PP = PPFEP1(E, P1, IT)$$

which in turn is transformed to an integer index IPP by

$$IPP = \underline{INDEXP}(PP)$$

where INDEXP(P) is the function that translates price to the corresponding integer index.

(b) The market price PP (represented by IPP) and the beginning stocks (represented by IC1) determine the quantity of carryover by the stocks rule C(IC1, IPP, IT). This in turn is translated into the integer index (IC) by

$$IC = \underline{INDEXC}[C(IC1, IP1, IT)]$$

where INDEXC is the function that translates quantities of stocks into the corresponding integer index.

In addition, the change of stocks DC is computed by

$$DC = CC(IC) - CC(IC1),$$

which, given the market price (calculated in (a) above), determines the final price by the function PFPPDC and its integer index (IP) by

$$IP = INDEXP[\underline{PFPPDC}(PP, DC, IT)].$$

In summary, each combination of indices (IC1, IP1, IE) results in a combination of indices (IC, IP) and a probability PRBCP(IT-1, IC1, IP1)*PRBE(IE) attached to it.

However, there might be more than one combination of (IC1, IP1, IE) that results in the *same* combination of (IC, IP). Hence to obtain the joint probability, PRBCP(IT, IC, IP), the program sums all the products

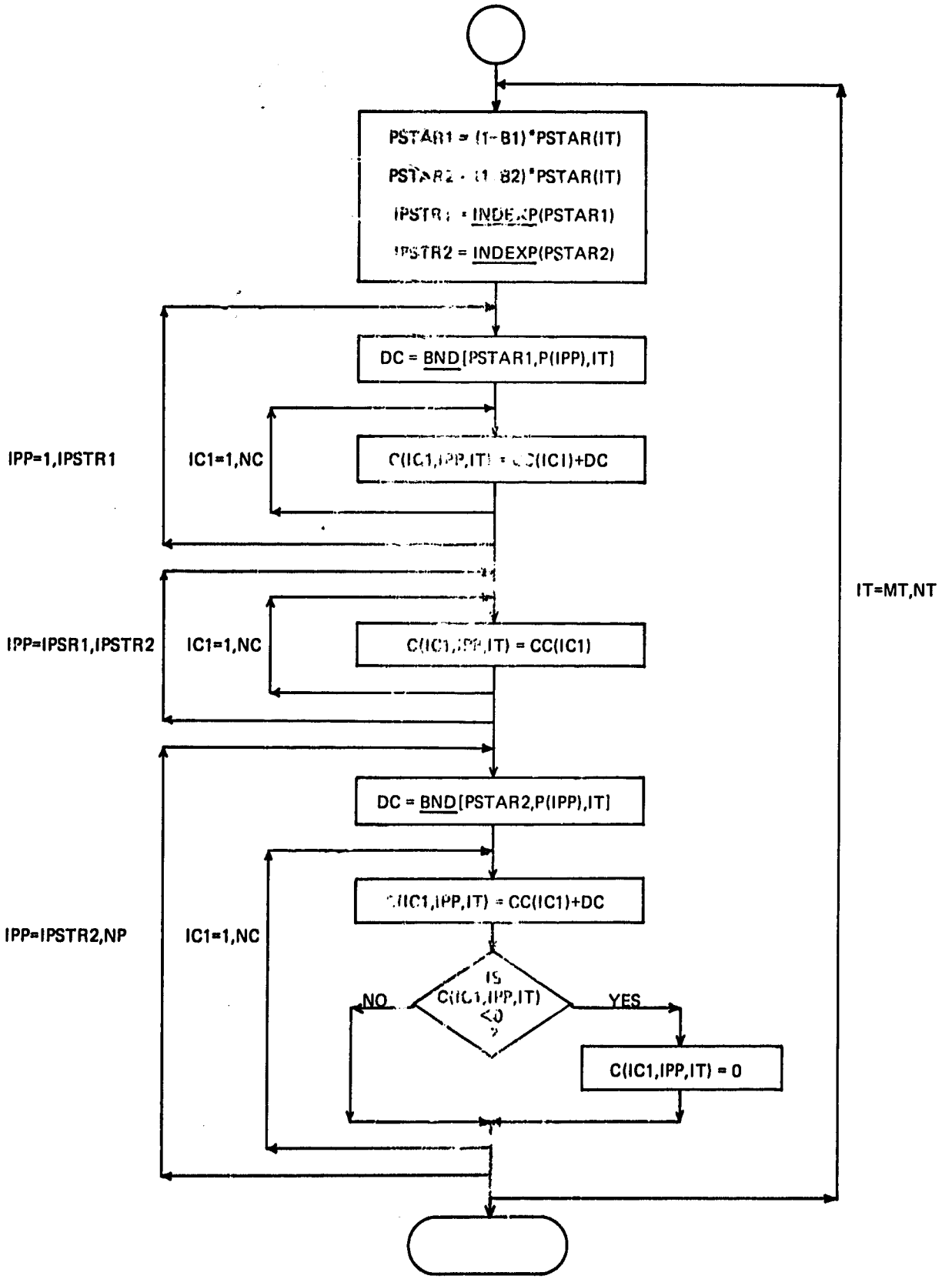
$$PRBCP(IT-1, IC1, IP1)*PRBE(IE),$$

corresponding to combinations of (IC1, IP1, IE), that result in the same (IP, IC). Figure 2 summarizes the above description in a flow chart of the program that calculates the joint probabilities.

Using the joint probabilities of stocks and prices, the program proceeds in calculating the marginal probabilities of prices and stocks, their cumulative probabilities, and some indicators of magnitudes and instability.

Marginal and cumulative probabilities and some indicators of instability. – The marginal probabilities of prices and stocks are calculated by summing over the stocks indices and price

Figure 1. A flow chart of the bounded price rule



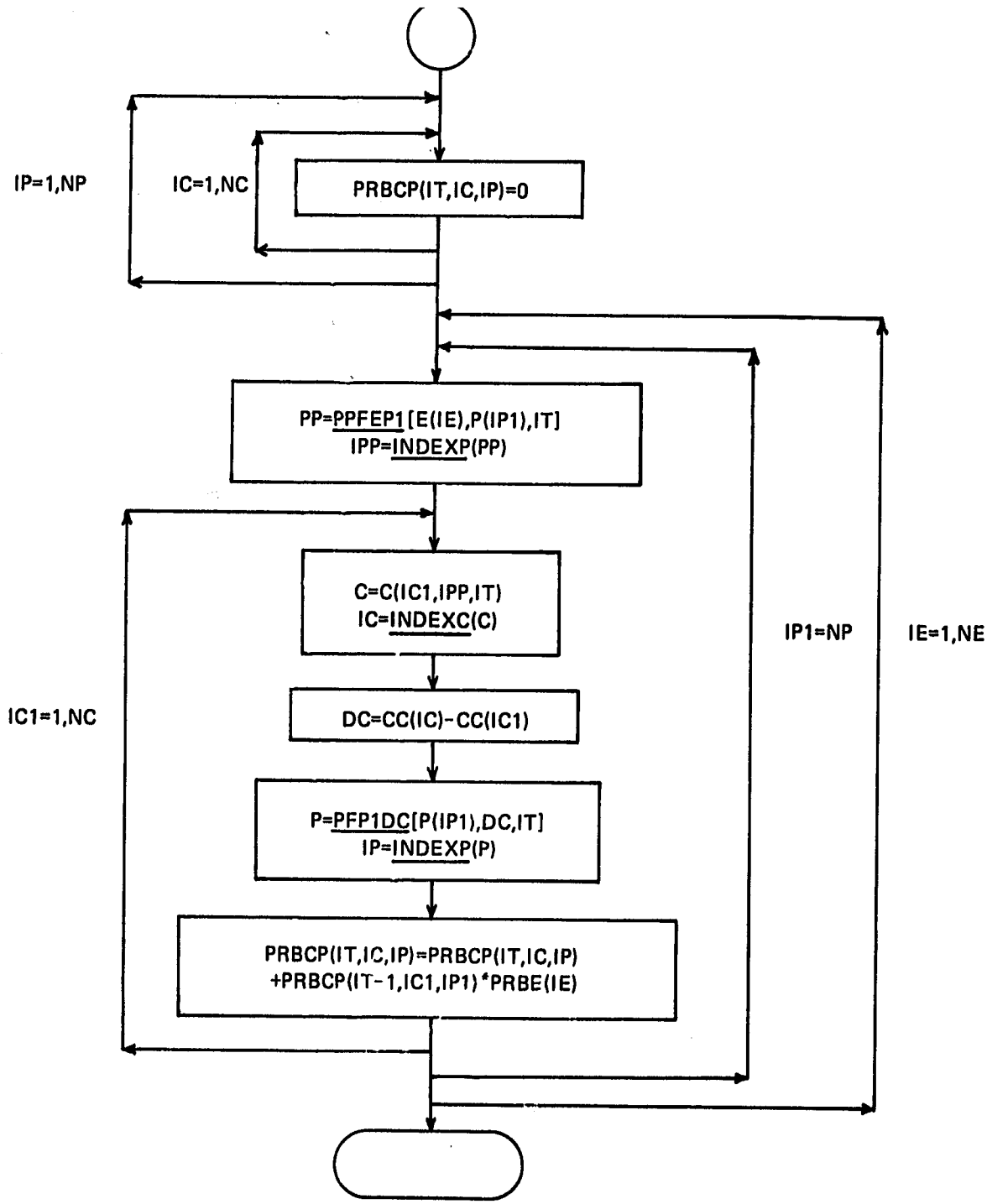


Figure 2. A flow chart of the computations of the joint probabilities of stocks and prices

indices respectively. More specifically, for a certain period IT:

$$PRBP(IP) = \sum_{IC} PRBCP(IT, IC, IP)$$

$$PRBC(IC) = \sum_{IP} PRBCP(IT, IC, IP)$$

where PRBP(IP) = probability [price = P(IP)]

and PRBC(IC) = probability [stocks = CC(IC)].

Using the marginal probabilities, the program then computes the following indicators for each period IT:

(1) Mean of price

$$MEANP(IT) = \sum_{IP} PRBP(IP)*(IP)$$

(2) Standard deviation of price

$$VARP(IT) \equiv [\sum_{IP} PRBP(IP)*\{P(IP) - MEANP(IT)\}^2]^{1/2}$$

(3) Coefficient of variation of price

$$CVP(IT) = VARP(IT)/MEANP(IT)$$

(4) Index of variability around the target price

$$VIP(IT) = [\sum_{IP} PRBP(IP)*\{P(IP) - PSTAR(IT)\}^2]^{1/2}$$

(5) Coefficient of variation around target price

$$CVTP(IT) = VTP(IT)/PSTAR(IT)$$

(6) Mean of stocks

$$MEANC(IT) = \sum_{IC} PRBC(IC)*CC(IC)$$

(7) Standard deviation of stocks

$$VARC(IT) = [\sum_{IC} PRBC(IC)*\{CC(IC) - MEANC(IT)\}^2]^{1/2}$$

(8) Coefficient of variation of stocks

$$CVC(IT) = VARC(IT)/MEANC(IT)$$

All the above indicators measure the magnitude and variability of price or stocks in a certain period IT. While the standard deviation and the coefficient of variation measure the average absolute and relative deviation around the mean respectively, VIP and CVTP measure the average absolute and relative deviation of prices around the target price respectively.

In addition, the program computes for each IT cumulative indicators for the whole period from MT through IT. These are:

(9) Discounted instability index

$$DIIN = \sum_{I=MT}^{IT} CVTP(I)^2 * 1/(1+DELTA)^{(IT-MT)}$$

(10) Instability index (not discounted)

$$IIN = \sum_{I=MT}^{IT} CVT(I)^2$$

(11) Average coefficient of variation

$$ACVTP = (IIN)^{1/2}/(IT-MT+1)$$

(This is a measure of the average deviation aroun target price for the whole period MT through IT.)

(12) Discounted mean of stocks

$$DMEANC = \sum_{I=MT}^{IT} MEANC(I)* 1/(1+DELTA)$$

(13) Average (nondiscounted) mean of stocks

$$AMEANC = \sum_{I=MT}^{IT} MEANC(I)/(IT-MT+$$

Finally, the program computes the cumulative p of prices and stocks by

$$PRBP(IP) = \sum_{I=1}^{IP} PRBP(I)$$

$$PRBC(IC) = \sum_{I=1}^{IC} PRBC(I)$$

where PRBP(IP) now stands for probability [pric

and PRBC(IC) now stands for probability [stock

This concludes the description of the computatic gram. For more details see the flow chart in Appendi

APPENDIX A

TABLES

Appendix table 1. Wheat, world model with alternative bounded price rules, for selected years, 1975-1985, with the assumptions of a zero beginning reserve stock[1] and alternative price elasticities of demand

Measure	Price elasticity of demand of -.2[2]							Price elasticity of demand of -.3[3]						
	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100		
		1975	1980	1985	1975	1980	1985		1975	1980	1985	1975	1980	1985
Probability in percent of market price being[4]														
at or less than 50	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
at or less than 80	23.9	0.0	0.0	0.0	23.9	23.9	23.9	13.2	0.0	0.0	0.0	13.2	13.2	13.2
at or less than 90	36.7	36.7	36.7	36.7	36.7	36.7	36.7	31.0	31.0	31.0	31.0	31.0	31.0	31.0
at or less than 100	51.0	51.0	51.0	51.0	51.0	51.0	51.0	53.1	53.1	53.1	53.1	53.1	53.1	53.1
at or less than 110	67.1	67.1*	81.8*	85.8*	67.1	67.1	67.1	74.4	74.4*	84.7*	87.7*	74.4	74.4	74.4
at or less than 120	79.3	79.3	89.5	92.0	79.3*	86.6*	89.4*	89.1	89.1	94.3	95.6	89.1*	91.7*	93.0*
at or less than 150	99.4	99.4	99.8	99.9	99.4	99.8	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average market price	100	106	103	102	103	102	101	100	103	102	101	101	101	101
Av. variation around the target price in %	24.3	18.3	14.2	13.3	20.5	18.6	18.1	16.3	13.0	11.1	10.6	15.0	14.6	14.4
Probability of being out of stocks	–	67.1	30.7	23.5	79.3	39.8	29.8	–	74.4	34.9	26.8	89.1	56.4	42.6
Average reserve stock in million tons[5]	–	4.5	19.5	31.2	2.3	11.2	18.6	–	3.3	15.1	24.8	1.0	5.3	9.4
Average world production in million tons	–	389	455	532	389	455	532	–	389	455	532	389	455	532
Percent stocks are of production	–	1.15	4.29	5.87	0.59	2.46	3.50	–	0.85	3.32	4.66	0.26	1.17	1.76
Coefficient of variation in stocks in % of the mean	–	181	108	98	238	124	109	–	209	116	103	331	153	127

[1] The assumption of zero beginning reserve stocks does not mean "no stocks." We assume that working stocks for normal intra-year business operations are in being.

[2] The demand function is assumed to be linear, hence the elasticity of -.2 holds only at the mean.

[3] The demand function is assumed to be linear, hence the elasticity of -.3 holds only at the mean.

[4] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[5] The actual reserve stock for any given year may be greater or less than the estimate presented on this line, since these estimates are mean averages of possible stock quantities. Each level of reserve stocks has a probability, but those probabilities are not presented here; they are discussed in the technical section of this report.

Appendix table 2. Wheat, world model with alternative bounded price rules, for selected years, 1975 1985, with the assumptions of a beginning reserve stock of 20 million tons[1] and alternative price elasticities of demand

Measure	Price elasticity of demand of −.2[2]							Price elasticity of demand of −.3[3]						
	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100		
		1975	1980	1985	1975	1980	1985		1975	1980	1985	1975	1980	1985
'obability in per- ınt of market price ɜing[4]														
ıt or less than 50	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ıt or less than 80	23.9	0.0	0.0	0.0	23.9	23.9	23.9	13.2	0.0	0.0	0.0	13.2	13.2	13.2
ıt or less than 90	36.7	36.7	36.7	36.7	36.7	36.7	36.7	31.0	31.0	31.0	31.0	31.0	31.0	31.0
ıt or less than 100	51.0	51.0	51.0	51.0	51.0	51.0	51.0	53.1	53.1	53.1	53.1	53.1	53.1	53.1
ıt or less than 110	67.1	92.9*	86.9*	87.9*	67.1	67.1	67.1	74.4	95.8*	90.4*	90.2*	74.4	74.4	74.4
ıt or less than 120	79.3	97.9	92.7	93.2	97.9*	93.1*	92.5*	89.1	100.0	96.8	96.6	100.0*	98.2*	96.9*
ıt or less than 150	99.4	100.0	99.9	99.9	100.0	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
verage market price	100	101	102	102	100	101	101	100	100	101	101	100	100	100
v. variation around :he target price n %	24.3	10.2	12.8	12.7	15.9	17.1	17.4	16.3	8.8	10.1	10.2	13.5	13.7	13.9
'obability of being ɔut of stocks	–	10.9	21.3	19.9	4.2	16.2	19.8	–	5.6	19.7	20.8	2.1	7.1	13.4
verage reserve ;tock in million :ons[5]	–	20.5	28.1	37.2	20.1	22.7	27.2	–	20.3	25.1	32.0	20.0	20.4	21.7
verage world pro- duction in million :ons	–	389	455	532	389	455	532	–	389	455	532	389	455	532
ırcent stocks are of ɔroduction	–	5.27	6.18	7.00	5.17	4.99	5.11	–	5.22	5.52	6.02	5.14	4.49	4.08
ɔefficient of varia- :ion in stocks in % ɔf the mean	–	59	92	91	41	81	91	–	51	89	93	25	58	75

'he assumption of beginning reserve stocks of 20 million tons does not mean that this is the total of all stocks. We assume that working stocks for ıormal intra-year business operations are in being and in addition to the 20 million tons of beginning reserve stocks.

'he demand function is assumed to be linear, hence the elasticity of −.2 holds only at the mean.

'he demand function is assumed to be linear, hence the elasticity of −.3 holds only at the mean.

'he starred probabilities give the probability of market price falling within the particular bounded price objective.

'he actual reserve stock for any given year may be greater or less than the estimate presented on this line, since these estimates are mean averages ıf possible stock quantities. Each level of reserve stocks has a probability, but those probabilities are not presented here, they are discussed in the echnical section of this report.

Appendix table 3. Rice, world model with alternative bounded price rules, for selected years, 1975-1985, with the assumptions of a zero beginning reserve stock[1] and alternative price elasticities of demand

Measure	Price elasticity of demand of -.2[2]							Price elasticity of demand of -.3[3]						
	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100		
		1975	1980	1985	1975	1980	1985		1975	1980	1985	1975	1980	1985
Probability in percent of market price being[4]														
at or less than 50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
at or less than 80	13.2	0.0	0.0	0.0	13.2	13.2	13.2	4.2	0.0	0.0	0.0	4.2	4.2	4.2
at or less than 90	31.0	31.0	31.0	31.0	31.0	31.0	31.0	22.3	22.3	22.3	22.3	22.3	22.3	22.3
at or less than 100	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1
at or less than 110	74.4	74.4*	84.6*	87.7*	74.4	74.4	74.4	83.6	83.6*	89.3*	90.8*	83.6	83.6	83.6
at or less than 120	89.1	89.1	94.3	95.4	89.1*	91.7*	92.7*	97.9	97.9	98.9	99.1	97.9*	98.1*	98.1*
at or less than 150	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average market price	100	103	102	101	101	101	101	100	101	101	101	100	100	100
Av. variation around the target price in %	16.3	13.0	11.1	10.6	15.0	14.6	14.4	10.8	9.3	8.7	8.5	10.7	10.7	10.7
Probability of being out of stocks	–	77.7	39.3	29.6	91.1	62.6	48.4	–	83.6	46.9	35.3	97.9	88.8	81.3
Average reserve stock in million tons[5]	–	1.3	5.9	9.6	0.4	2.1	3.5	–	0.8	3.7	6.1	0.05	0.3	5.2
Average world production in million tons	–	230	263	343	230	263	343	–	230	263	300	230	263	300
Percent stocks are of production	–	0.55	2.25	2.79	0.17	0.80	1.02	–	0.34	1.39	2.02	0.02	0.11	1.73
Coefficient of variation in stocks in % of the mean	–	224	117	105	358	158	131	–	259	130	113	687	288	219

[1] The assumption of zero beginning reserve stocks does not mean "no stocks." We assume that working stocks for normal intra-year business operations are in being.

[2] The demand function is assumed to be linear, hence the elasticity of -.2 holds only at the mean.

[3] The demand function is assumed to be linear, hence the elasticity of -.3 holds only at the mean.

[4] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[5] The actual reserve stock for any given year may be greater or less than the estimate presented on this line, since these estimates are mean averages of possible stock quantities. Each level of reserve stocks has a probability, but those probabilities are not presented here; they are discussed in the technical section of this report.

Appendix table 4. Rice, world model with alternative bounded price rules, for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 20 million tons[1] and alternative price elasticities of demand

Measure	Price elasticity of demand of -.2[2]							Price elasticity of demand of -.3[3]						
	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100		
		1975	1980	1985	1975	1980	1985		1975	1980	1985	1975	1980	1985
Probability in percent of market price being[4]														
at or less than 50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
at or less than 80	13.2	0.0	0.0	0.0	13.2	13.2	13.2	4.2	0.0	0.0	0.0	4.2	4.2	4.2
at or less than 90	31.0	31.0	31.0	31.0	31.0	31.0	31.0	22.3	22.3	22.3	22.3	22.3	22.3	22.3
at or less than 100	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1
at or less than 110	74.4	100.0*	97.8*	95.6*	74.4	74.4	74.4	83.6	100.0*	99.7*	98.7*	83.6	83.6	83.6
at or less than 120	89.1	100.0	99.4	98.5	100.0*	100.0*	99.8*	97.9	100.0	100.0	99.9	100.0*	100.0*	100.0*
at or less than 150	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average market price	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Av. variation around the target price in %	16.3	8.4	8.8	9.2	13.5	13.5	13.5	10.8	7.6	7.6	7.7	10.5	10.5	10.5
Probability of being out of stocks	–	0.0	4.5	9.8	0.0	0.1	0.7	–	0.0	0.9	4.0	0.0	0.0	0.0
Average reserve stock in million tons[5]	–	20.0	20.2	21.1	20.0	20.0	20.0	–	20.0	20.0	20.2	20.0	20.0	20.0
Average world production in million tons	–	230	263	343	230	263	343	–	230	263	300	230	263	300
Percent stocks are of production	–	8.70	7.69	6.16	8.70	7.69	5.83	–	8.70	7.62	6.73	8.70	7.62	6.66
Coefficient of variation in stocks in % of the mean	–	22	53	69	10	26	36	–	15	38	52	2.5	6.2	8.4

[1] The assumption of beginning reserve stocks of 20 million tons does not mean that this is the total of all stocks. We assume that working stocks for normal intra-year business operations are in being and in addition to the 20 million tons of beginning reserve stocks.

[2] The demand function is assumed to be linear, hence the elasticity of –.2 holds only at the mean.

[3] The demand function is assumed to be linear, hence the elasticity of –.3 holds only at the mean.

[4] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[5] The actual reserve stock for any given year may be greater or less than the estimate presented on this line, since these estimates are mean averages of possible stock quantities. Each level of reserve stocks has the probability, but those probabilities are not presented here; they are discussed in the technical section of this report.

Appendix table 5. Coarse grains, world model with alternative bounded price rules, for selected years, 1975-1985, with the assumptions of a zero beginning reserve stock[1] and alternative price elasticities of demand

Measure	Price elasticity of demand of -.3[2]							Price elasticitiy of demand of -.4[3]						
	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100		
		1975	1980	1985	1975	1980	1985		1975	1980	1985	1975	1980	1985
Probability in percent of market price being[4]														
at or less than 50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–	–	–
at or less than 80	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–	–	–
at or less than 90	17.8	17.8	17.8	17.8	17.8	17.8	17.8	10.9	10.9	10.9	10.9	–	–	–
at or less than 100	53.1	53.1	53.1	53.1	53.1	53.1	53.1	55.2	55.2	55.2	55.2	–	–	–
at or less than 110	86.8	86.8*	90.7*	92.4*	86.8	90.7	92.4	94.4	94.4*	94.4*	94.4*	–	–	–
at or less than 120	100.0	100.0	100.0	100.0	100.0*	100.0*	100.0*	97.9	100.0	100.0	100.0	–	–	–
at or less than 150	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	–	–	–
Average market price	100	101	100	100	101	100	100	100	100	100	100	–	–	–
Av. variation around the target price in %	9.2	8.3	7.9	7.8	8.3	7.9	7.8	6.8	6.8	6.8	6.8	–	–	–
Probability of being out of stocks	–	86.8	51.8	38.5	86.8	51.8	38.5	0.0	0.0	0.0	0.0	–	–	–
Average reserve stock in million tons[5]	–	1.35	7.22	12.1	1.35	7.22	12.1	–	–	–	–	–	–	–
Average world production in million tons	–	708	814	1067	708	814	1067	–	–	–	–	–	–	–
Percent stocks are of production	–	0.19	0.89	1.13	0.19	0.89	1.13	–	–	–	–	–	–	–
Coefficient of variation in stocks in % of the mean	–	294	140	119	294	140	119	–	–	–	–	–	–	–

[1] The assumption of zero beginning reserve stocks does not mean "no stocks." We assume that working stocks for normal intra-year business operations are in being.

[2] The demand function is assumed to be linear, hence the elasticity of -.3 holds only at the mean.

[3] The demand function is assumed to be linear, hence the elasticity of -.4 holds only at the mean.

[4] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[5] The actual reserve stock for any given year may be greater or less than the estimate presented on this line, since these estimates are mean averages of possible stock quantities. Each level of reserve stocks has a probability, but those probabilities are not presented here; they are discussed in the technical section of this report.

Appendix table 6. Coarse grains, world model with alternative bounded price rules, for selected years, 1975-1985, with the assumptions of a beginning reserve stock of 20 million tons[1] and alternative price elasticities of demand

Measure	Price elasticity of demand of -.3[2]							Price elasticity of demand of -.4[3]						
	Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100			Free market	Plus or minus 10% of the target price, 100			Plus or minus 20% of the target price, 100		
		1975	1980	1985	1975	1980	1985		1975	1980	1985	1975	1980	1985
Probability in percent of market price being[4]														
at or less than 50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–	–	–
at or less than 80	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–	–	–
at or less than 90	17.8	17.8	17.8	17.8	17.8	17.8	17.8	10.9	10.9	10.9	10.9	–	–	–
at or less than 100	53.1	53.1	53.1	53.1	53.1	53.1	53.1	55.2	55.2	55.2	55.2	–	–	–
at or less than 110	86.8	100.0*	97.1*	95.9*	100.0	97.1	95.9	94.4	94.4*	94.4*	94.4*	–	–	–
at or less than 120	100.0	100.0	100.0	100.0	100.0*	100.0*	100.0*	97.9	100.0	100.0	100.0	–	–	–
at or less than 150	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	–	–	–
Average market price	100	100	100	100	100	100	100	100	100	100	100	–	–	–
Av. variation around the target price in %	9.2	7.2	7.4	7.5	7.2	7.4	7.5	6.8	6.8	6.8	6.8	–	–	–
Probability of being out of stocks	–	1.3	10.8	16.8	1.3	10.8	16.8	–	0.0	0.0	0.0	–	–	–
Average reserve stock in million tons[5]	–	20.0	21.0	23.0	20.0	21.0	23.0	–	20.0	20.0	20.0	–	–	–
Average world production in million tons	–	708	814	1067	708	814	1067	–	708	814	1067	–	–	–
Percent stocks are of production	–	2.82	2.58	2.16	2.82	2.58	2.16	–	2.82	2.46	1.88	–	–	–
Coefficient of variation in stocks in % of the mean	–	30	68	82	30	68	82	–	0	0	0	–	–	–

[1] The assumption of beginning reserve stocks of 20 million tons does not mean that this is the total of all stocks. We assume that working stocks for normal intra-year business operations are in being and in addition to the 20 million tons of beginning reserve stocks.

[2] The demand function is assumed to be linear, hence the elasticity of -.3 holds only at the mean.

[3] The demand function is assumed to be linear, hence the elasticity of -.4 holds only at the mean.

[4] The starred probabilities give the probability of market price falling within the particular bounded price objective.

[5] The actual reserve stock for any given year may be greater or less than the estimate presented on this line, since these estimates are mean averages of possible stock quantities. Each level of reserve stocks has a probability, but those probabilities are not presented here; they are discussed in the technical section of this report.

APPENDIX B

A FLOW CHART OF THE COMPUTATIONAL PROGRAM

Part VII gave a description of the computations procedure. In this appendix a flow chart of computations is presented. It is based on a FORTRAN program used in this study.[13] Some details of the program have been omitted and slight changes have been introduced in the flow chart for convenience.

Notes and explanations of the main symbols are in the order in which they appear in the flow chart. Underlined names indicate functions. A flow chart of the functions is presented at the end. The numbers in circles ◯ are related to the numbered connectors in the flow chart.

①→② Defining the approximation to prices, stocks, and stochastic disturbance.

NP = number of integer indices of price

PO = value of price corresponding to the first price index

UP = interval between any two points of price

NC = number of integer indices of stocks

CO = quantity of stocks corresponding to the first stocks index

UC = interval between any two points of stocks

The first do-loop defines a correspondence from integer indices to prices, P(IP). The inverse correspondence (i.e., from price to indices) is defined by the function INDEXP(P) (all functions are described at the end). The second do-loop defines a correspondence from integer indices to stocks, CC(IC). The inverse correspondence is defined by the function INDEXC (IC) (functions are described at the end).

EO = number of standard deviations (+ or -) that define the range of the stochastic disturbance (E)

UE = the interval between any two points of the stochastic disturbance (expressed in standard deviations)

NE = number of integer indices of the stochastic disturbance

The last part of the program before ② defines an approximation to the standardized normal distribution by a discrete probability function.

PRBE(IE) = the probability that the random disturbance will obtain the value E(IE)

The correspondence E(IE) from the integer indices IE to values of E is defined in the first row in the large box before ②.

②→③

MT = first period of the planning period

NT = last period of the planning period

NMT = total number of periods

The do-loop in K=1, 2, ..., NMT defines a series of target prices PSTAR(KT) KT=1, 2, ..., NMT. The function TARGET (IT) must be determined and set by the user of the program. (An example is given in the description of the function at the end.)

LAMBDA = λ, the desired marginal rate of substitution of stability for cost

THETA = θ, unit storage cost per period

DELTA = δ, discount rate

After reading DELTA, the discount coefficient $(1/1+\delta)$ replaces the value of δ in the same variable.

③→④ Calculation of the minimization stocks rules.

IC1 = integer index of beginning stocks (C1), i.e., stocks of previous period

IPP = integer index of free market price (PP)

DC = ΔC, the change of stocks

IC = integer index of current stocks

PFPPD(PP,DC,IT) = a function that calculates the final price of time IT, when the market price is PP and the change of stocks is DC (see description of functions at the end)

C(IC1,IPP,IT) = the optimal carryover that minimizes the objective function for beginning stocks CC(IC1) and market price P(IPP)

PRICE(IC1,IPP) = final price after applying the optimal rule, when the beginning stocks are CC(IC1) and the market price is P(IPP)

V(IC1,IPP) = the minimum value of the objective function, given CC(IC1) and P(IPP)

④→⑤ Calculation of the expectation of V(IC1,IPP).

LAG = an index that indicates whether there is a lagged price effect in the model (LAG = 0 if NOT, LAG = 1 if YES)

PPFEP1(E,P1,IT) = a function that calculates the free market price (PP) at time IT, when the lagged price is P1 and the disturbance is E (see description of functions at the end)

EV(IC1,IP1) = the expected value of V(IC1,IPP) when beginning stocks are CC(IC1) and lagged price is P(IP1)

EV(IC1) = similar to EV(IC1,IP1), but for the case of no lagged price

Note: When there is no lagged price effect, EV depends only on the beginning stocks (C1) and much computation time can be saved by using the right-hand side of ④→⑤.

⑤→⑥ Preparation for probability computation.

C10 = beginning stocks of the first period (MT)

P10 = lagged price of the first period

PRBCP(J,IC,IP) = joint probability of stocks CC(IC) and price P(IP)

[13] A printout of the FORTRAN program is available on request from the senior author at the University of Minnesota.

PRBCP(J1,IC1,IP1) = joint probability of stocks CC(IC1) and price P(IP1) of previous period

Note: When there is no lagged price effect, it is not necessary to calculate the joint probabilities of stocks and price. However, the space of PRBCP is used for the (marginal) probabilities of stocks and prices.

PRBCP(·,IC,1) is used for the probability of stocks and

PRBCP(·,IP,2) is used for the probability of prices.

For the calculation of probabilities of period IT, it is not necessary to remember all the probabilities that have been computed for previous periods but only the ones of IT-1. The use of the indices J and J1 enables one to use a space for only two periods, namely the current one and the previous one.

J = an index indicating that the joint probability PRBCP is that of the current period of calculations. It may obtain values of 1 or 2:

$$J = \begin{cases} 1 \text{ if } K = 1, 3, 5 \ldots \\ 2 \text{ if } K = 2, 4, 6 \ldots \end{cases}$$

where K is the number of the current calculation period.

J1 = an index indicating that the joint probability PRBCP is that of the previous period. It always obtains the opposite value of J:

$$J1 = \begin{cases} 2 \text{ if } J = 1 \\ 1 \text{ if } J = 2 \end{cases}$$

⑦→⑧ Calculation of the joint probabilities when there is a lagged price effect.

⑦→⑨ Calculation of the marginal probabilities of stocks and prices in the no-lagged price case. There is no need to calculate the joint probabilities because in this case only the probability of stocks affects the probabilities of prices and stocks of the next period.

⑧→⑪ Calculations of marginal probabilities of pr and stocks in the case of lagged price effect.

PRBP(IP1) = marginal probability of P(IP1)

PRBC(IC1) = marginal probability of CC(IC1)

⑨→⑪ Transformation of the marginal probabiliti of stocks and prices to new variables in the case of no-lagg price. (The marginal probabilities have been calculated in ⑦→⑨.)

⑪→⑫ Calculation of various indicators and cumu probabilities of prices and stocks. The cumulative probabi replace the marginal one in the corresponding variables (PRBP and PRBC).

MEANC = mean of stocks

VARC = variance of stocks (Later, the standard deviation of stocks replaces the variance in the same variable.)

CVC = coefficient of variation of stocks

MEANP = mean of price

VARP = variance of price (Later, the standard deviation of price replaces the variance i the same variable.)

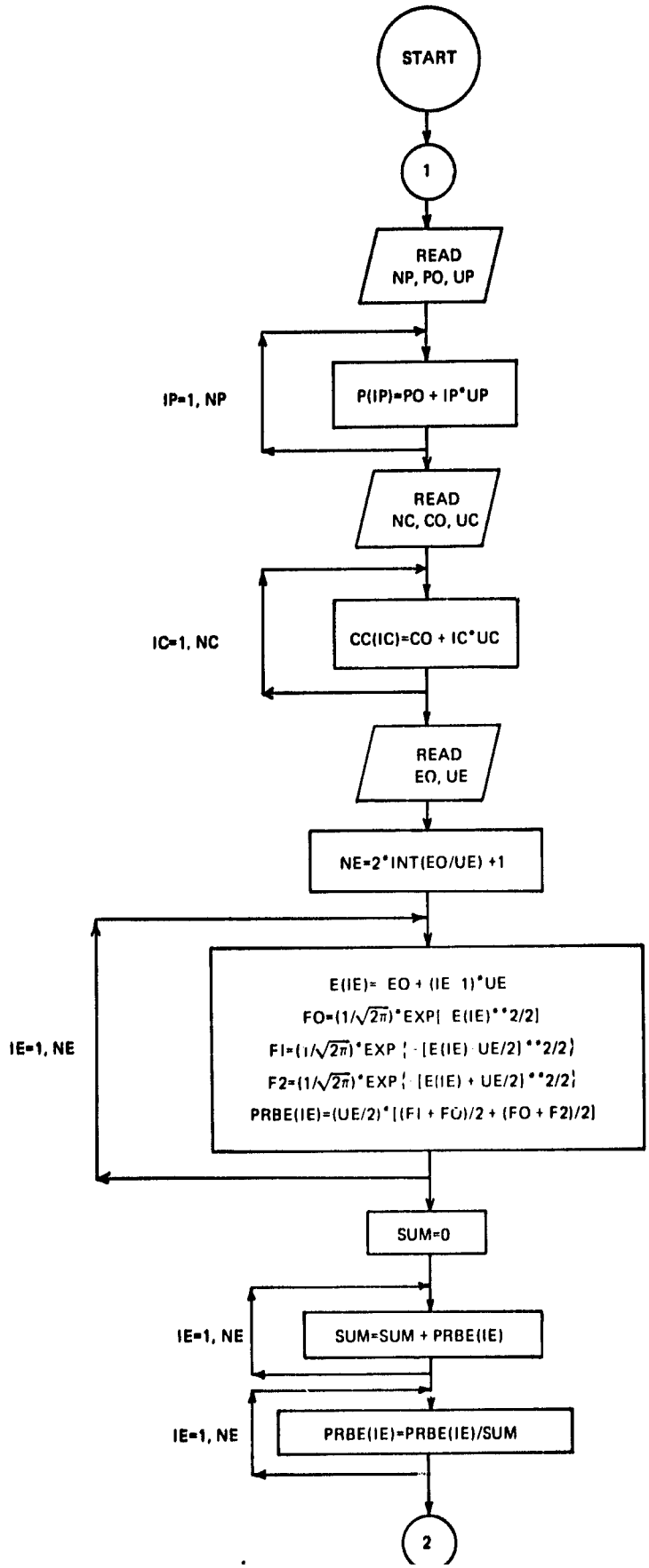
IIN = accumulated price instability index

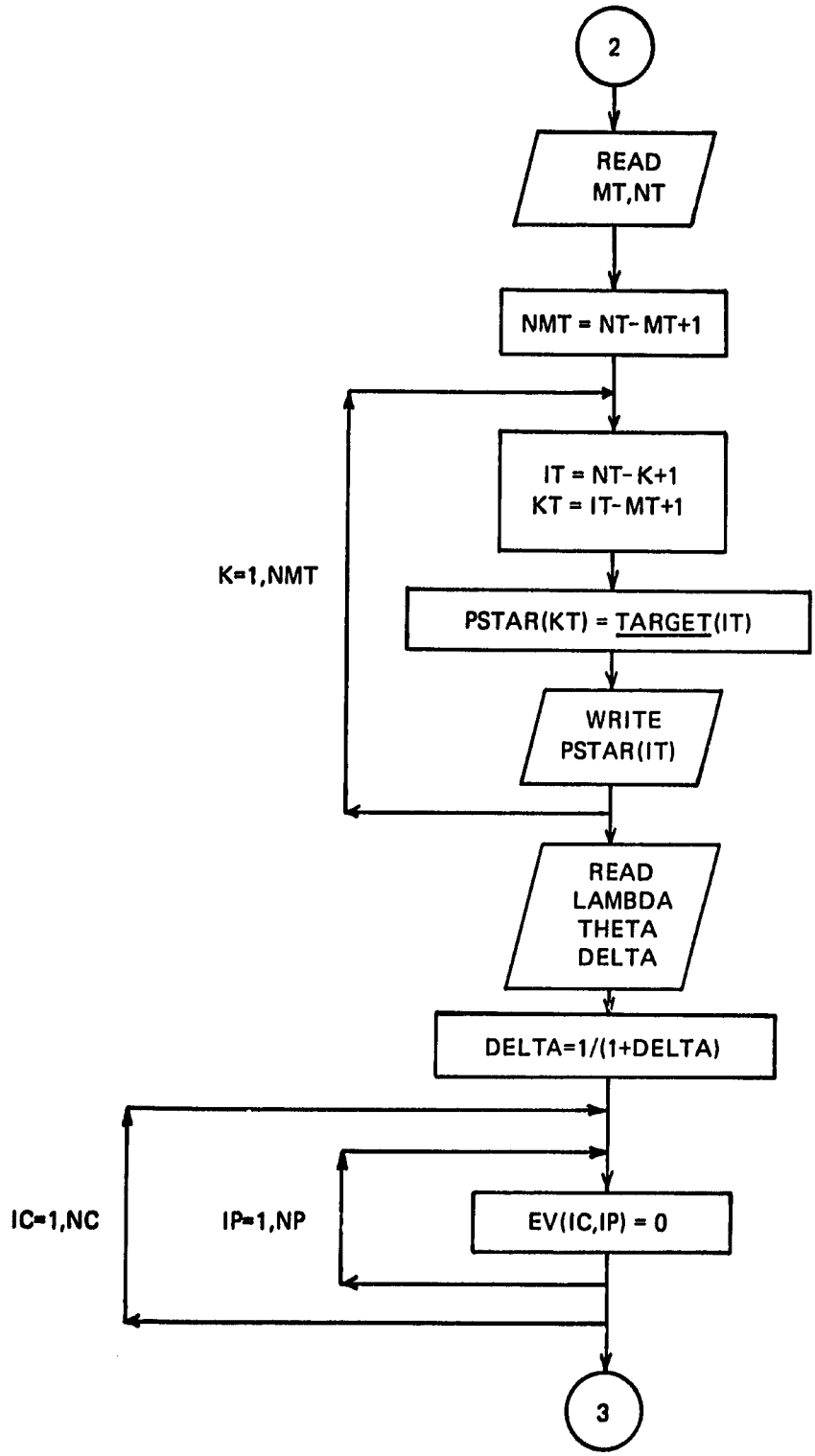
DIIN = discounted accumulated price instability index

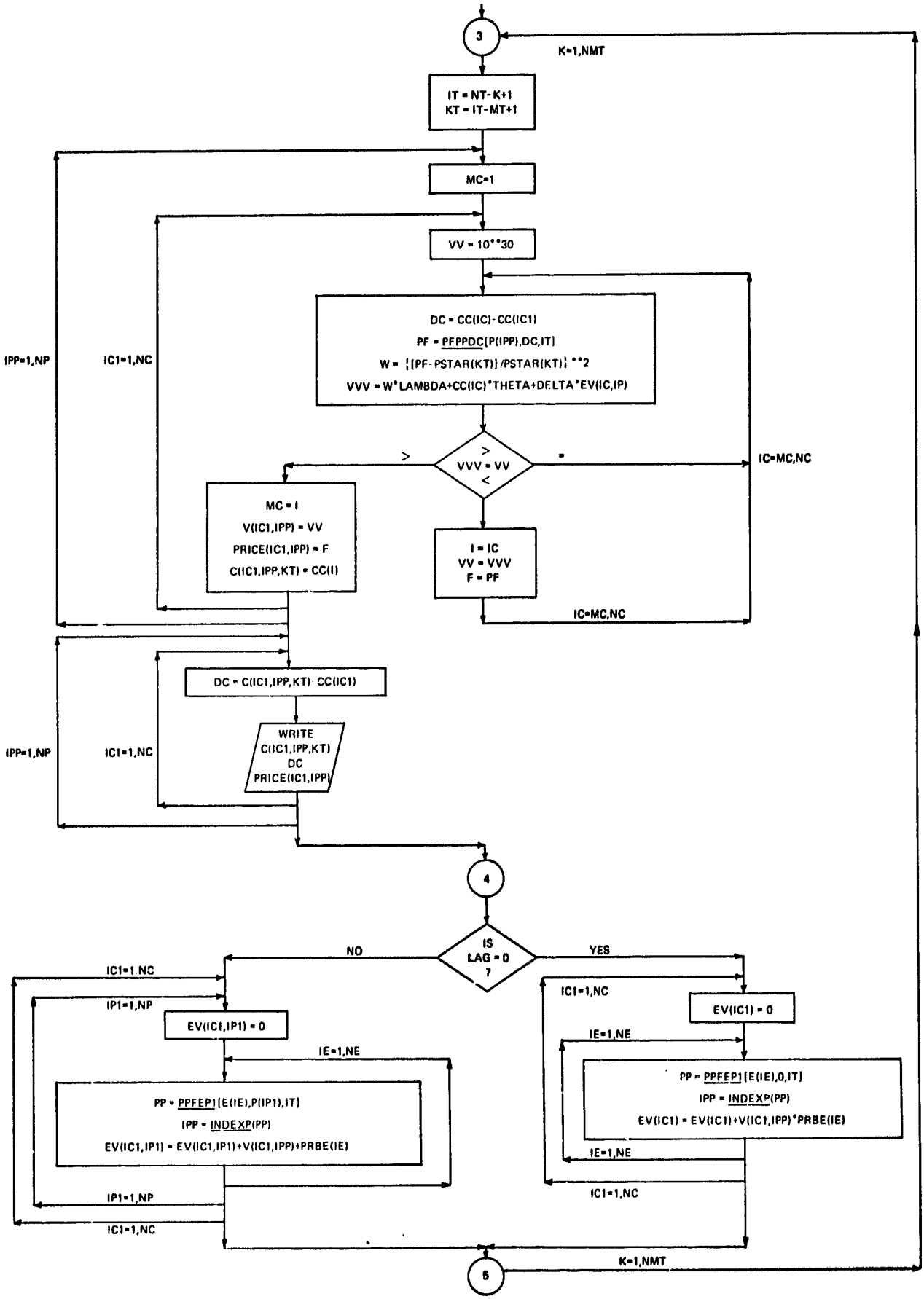
ACVTP = average coefficient of variation of prices around the target prices

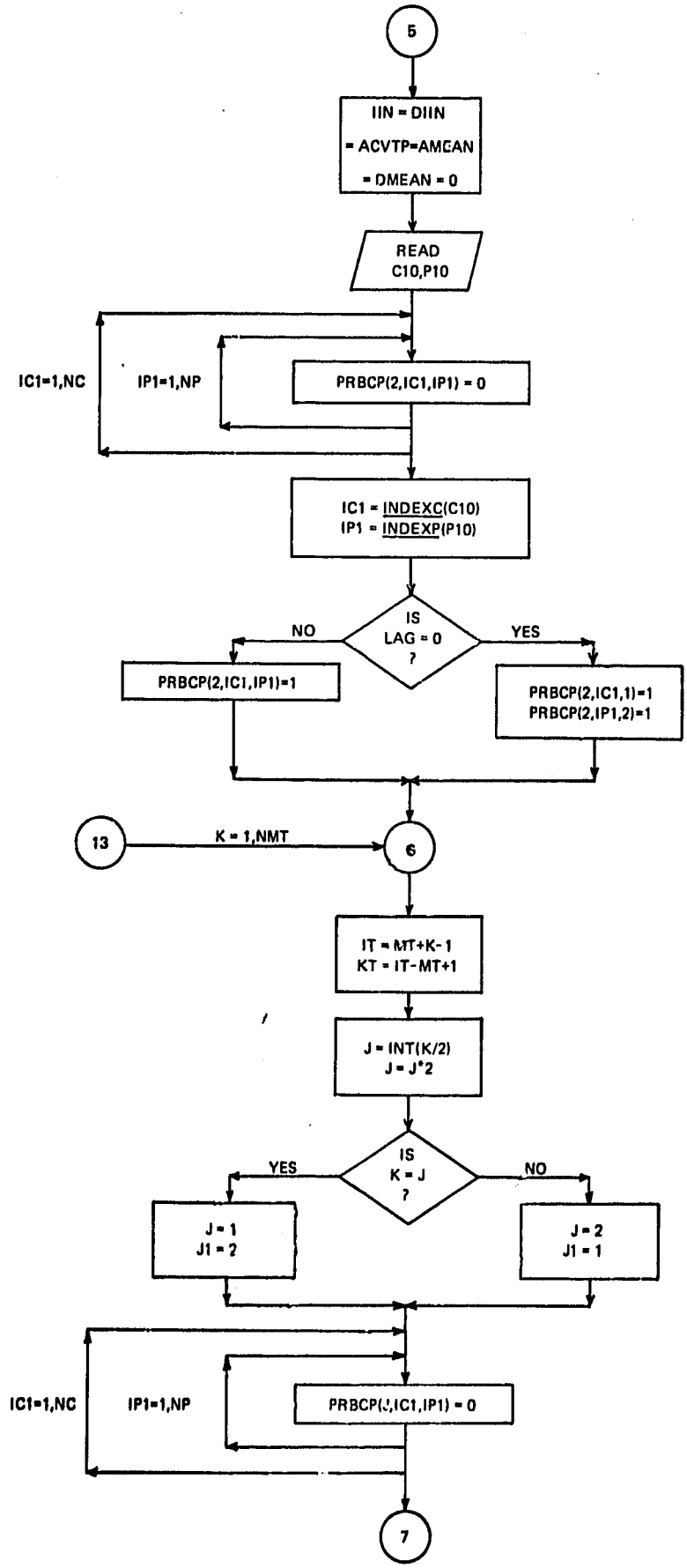
DMEANC = discounted accumulated mean of stocks

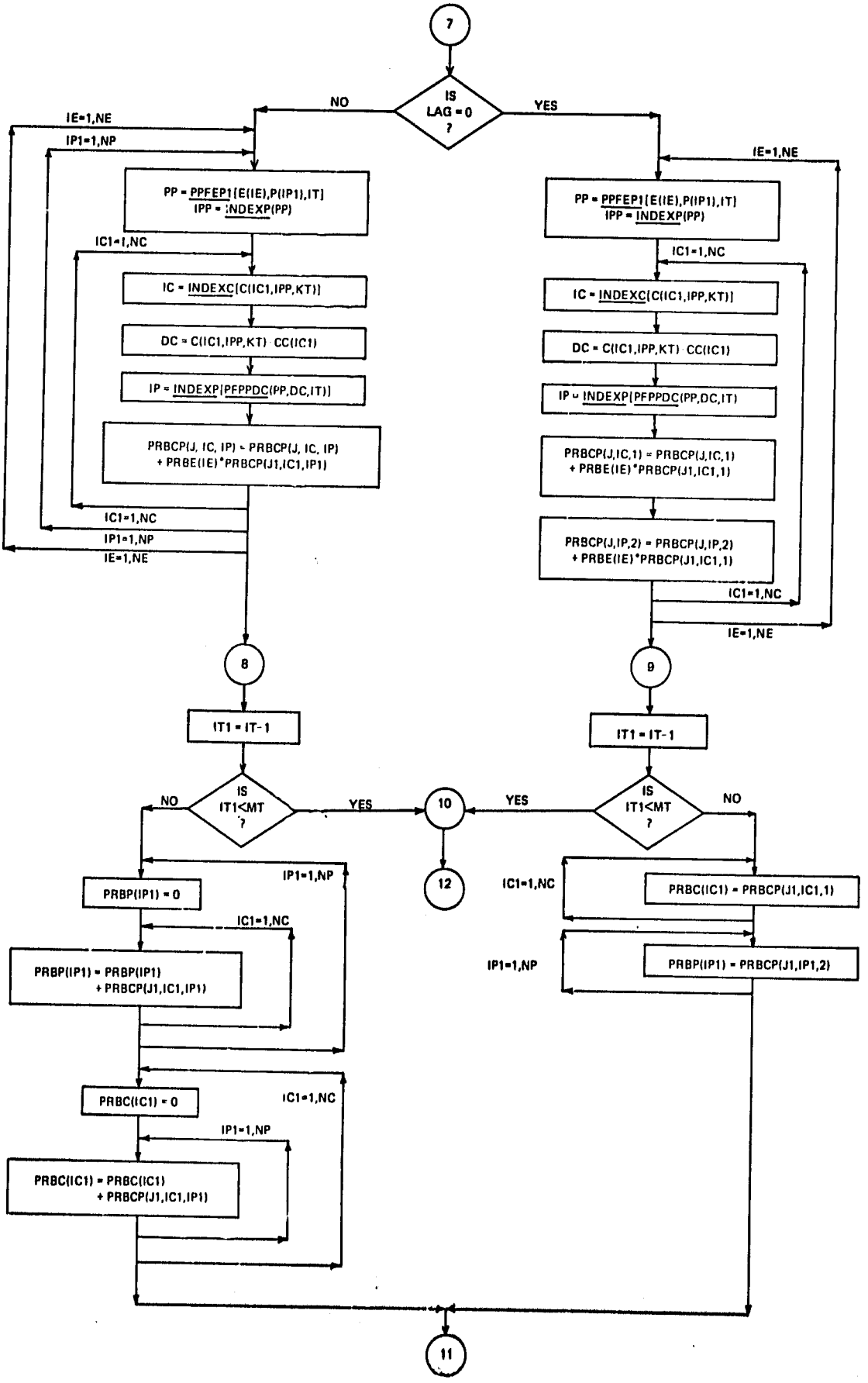
AMEANC = average mean of stocks.

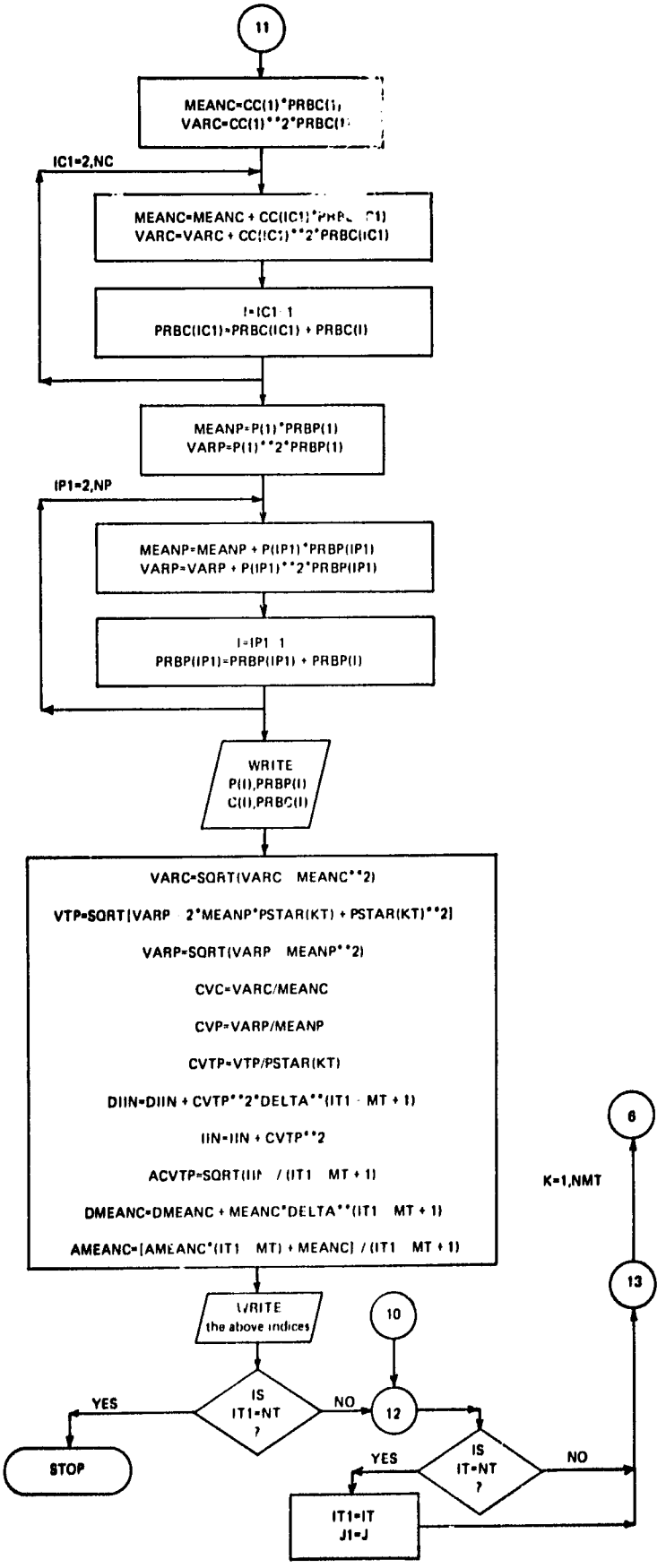

START
1
READ
NP, PO, UP
IP=1, NP
P(IP)=PO + IP*UP
READ
NC, CO, UC
IC=1, NC
CC(IC)=CO + IC*UC
READ
EO, UE
NE=2*INT(EO/UE) +1
IE=1, NE
E(IE)= EO + (IE 1)*UE
FO=(1/√2π)*EXP[E(IE)**2/2]
F1=(1/√2π)*EXP{ [E(IE) UE/2]**2/2}
F2=(1/√2π)*EXP{ [E(IE) + UE/2]**2/2}
PRBE(IE)=(UE/2)*[(F1 + FO)/2 + (FO + F2)/2]
SUM=0
IE=1, NE
SUM=SUM + PRBE(IE)
IE=1, NE
PRBE(IE)=PRBE(IE)/SUM
2


2
READ
MT,NT
NMT = NT- MT+1
IT = NT- K+1
KT = IT- MT+1
K=1,NMT
PSTAR(KT) = TARGET(IT)
WRITE
PSTAR(IT)
READ
LAMBDA
THETA
DELTA
DELTA=1/(1+DELTA)
IC=1,NC
IP=1,NP
EV(IC,IP) = 0
3


3
K=1,NMT
IT = NT-K+1
KT = IT-MT+1
MC=1
VV = 10**30
DC = CC(IC)-CC(IC1)
PF = PFPPDC[P(IPP),DC,IT]
W = {[PF-PSTAR(KT)]/PSTAR(KT)}**2
VVV = W*LAMBDA+CC(IC)*THETA+DELTA*EV(IC,IP)
IPP=1,NP
IC1=1,NC
>
VVV = VV
<
=
IC=MC,NC
MC = I
V(IC1,IPP) = VV
PRICE(IC1,IPP) = F
C(IC1,IPP,KT) = CC(I)
I = IC
VV = VVV
F = PF
IC=MC,NC
DC = C(IC1,IPP,KT)-CC(IC1)
WRITE
C(IC1,IPP,KT)
DC
PRICE(IC1,IPP)
IPP=1,NP
IC1=1,NC
4
IS
LAG = 0
?
NO
YES
IC1=1,NC
IP1=1,NP
EV(IC1,IP1) = 0
IE=1,NE
PP = PPFEP1[E(IE),P(IP1),IT]
IPP = INDEXP(PP)
EV(IC1,IP1) = EV(IC1,IP1)+V(IC1,IPP)*PRBE(IE)
IP1=1,NP
IC1=1,NC
IC1=1,NC
EV(IC1) = 0
IE=1,NE
PP = PPFEP1[E(IE),0,IT]
IPP = INDEXP(PP)
EV(IC1) = EV(IC1)+V(IC1,IPP)*PRBE(IE)
IE=1,NE
IC1=1,NC
5
K=1,NMT


5
IIN = DIIN
= ACVTP=AMEAN
= DMEAN = 0
READ
C10,P10
IC1=1,NC
IP1=1,NP
PRBCP(2,IC1,IP1) = 0
IC1 = INDEXC(C10)
IP1 = INDEXP(P10)
IS
LAG = 0
?
NO
YES
PRBCP(2,IC1,IP1)=1
PRBCP(2,IC1,1)=1
PRBCP(2,IP1,2)=1
13
K = 1,NMT
6
IT = MT+K-1
KT = IT-MT+1
J = INT(K/2)
J = J*2
IS
K = J
?
YES
NO
J = 1
J1 = 2
J = 2
J1 = 1
IC1=1,NC
IP1=1,NP
PRBCP(J,IC1,IP1) = 0
7


7
IS LAG = 0 ?
NO
YES
IE=1,NE
IP1=1,NP
PP = PPFEP1(E(IE),P(IP1),IT)
IPP = INDEXP(PP)
IC1=1,NC
IC = INDEXC(C(IC1,IPP,KT))
DC = C(IC1,IPP,KT) - CC(IC1)
IP = INDEXP(PFPPDC(PP,DC,IT))
PRBCP(J, IC, IP) = PRBCP(J, IC, IP) + PRBE(IE)*PRBCP(J1,IC1,IP1)
IC1=1,NC
IP1=1,NP
IE=1,NE
8
IT1 = IT-1
IS IT1<MT ?
NO
YES
10
12
PRBP(IP1) = 0
IP1=1,NP
IC1=1,NC
PRBP(IP1) = PRBP(IP1) + PRBCP(J1,IC1,IP1)
PRBC(IC1) = 0
IC1=1,NC
IP1=1,NP
PRBC(IC1) = PRBC(IC1) + PRBCP(J1,IC1,IP1)
11
IE=1,NE
PP = PPFEP1(E(IE),P(IP1),IT)
IPP = INDEXP(PP)
IC1=1,NC
IC = INDEXC(C(IC1,IPP,KT))
DC = C(IC1,IPP,KT) - CC(IC1)
IP = INDEXP(PFPPDC(PP,DC,IT))
PRBCP(J,IC,1) = PRBCP(J,IC,1) + PRBE(IE)*PRBCP(J1,IC1,1)
PRBCP(J,IP,2) = PRBCP(J,IP,2) + PRBE(IE)*PRBCP(J1,IC1,1)
IC1=1,NC
IE=1,NE
9
IT1 = IT-1
IS IT1<MT ?
YES
NO
IC1=1,NC
PRBC(IC1) = PRBCP(J1,IC1,1)
IP1=1,NP
PRBP(IP1) = PRBCP(J1,IP1,2)


11
MEANC=CC(1)*PRBC(1)
VARC=CC(1)**2*PRBC(1)
IC1=2,NC
MEANC=MEANC + CC(IC1)*PRBC(IC1)
VARC=VARC + CC(IC1)**2*PRBC(IC1)
I=IC1-1
PRBC(IC1)=PRBC(IC1) + PRBC(I)
MEANP=P(1)*PRBP(1)
VARP=P(1)**2*PRBP(1)
IP1=2,NP
MEANP=MEANP + P(IP1)*PRBP(IP1)
VARP=VARP + P(IP1)**2*PRBP(IP1)
I=IP1-1
PRBP(IP1)=PRBP(IP1) + PRBP(I)
WRITE
P(I),PRBP(I)
C(I),PRBC(I)
VARC=SQRT(VARC - MEANC**2)
VTP=SQRT[VARP - 2*MEANP*PSTAR(KT) + PSTAR(KT)**2]
VARP=SQRT(VARP - MEANP**2)
CVC=VARC/MEANC
CVP=VARP/MEANP
CVTP=VTP/PSTAR(KT)
DIIN=DIIN + CVTP**2*DELTA**(IT1 - MT + 1)
IIN=IIN + CVTP**2
ACVTP=SQRT(IIN / (IT1 - MT + 1)
DMEANC=DMEANC + MEANC*DELTA**(IT1 - MT + 1)
AMEANC=[AMEANC*(IT1 - MT) + MEANC] / (IT1 - MT + 1)
WRITE
the above indices
IS
IT1=NT
?
YES
STOP
NO
10
12
IS
IT=NT
?
YES
NO
IT1=IT
J1=J
K=1,NMT
6
13

Functions

INDEX P(P), INDEX (C)

These functions define the correspondence from prices and stocks to integer indices.

TARGET, PF PPDC, PPF EP

These three functions should be supplied by the user of the program according to the specification of the demand and supply model. The functions presented here are examples based on the following simple linear model. We denote parameters by small letters, the numerical values of which are inserted in the program.

Demand function: $Y_{IT} = (a_o - a_1 P_{IT} + E_d)(1 + g_d)^{(IT-MT)}$

Supply function: $X_{IT} = (b_o + b_1 P_{IT-1} + E_s)(1 + g_s)^{(IT-MT)}$

E_d and E_s are distributed normally with zero mean and standard deviations s_s and s_d respectively.

TARGET(IT)

This function defines a series of target prices. In the present example, the target prices are defined as the long-run equilibrium prices (i.e., $P_{IT} = P_{IT-1}$).

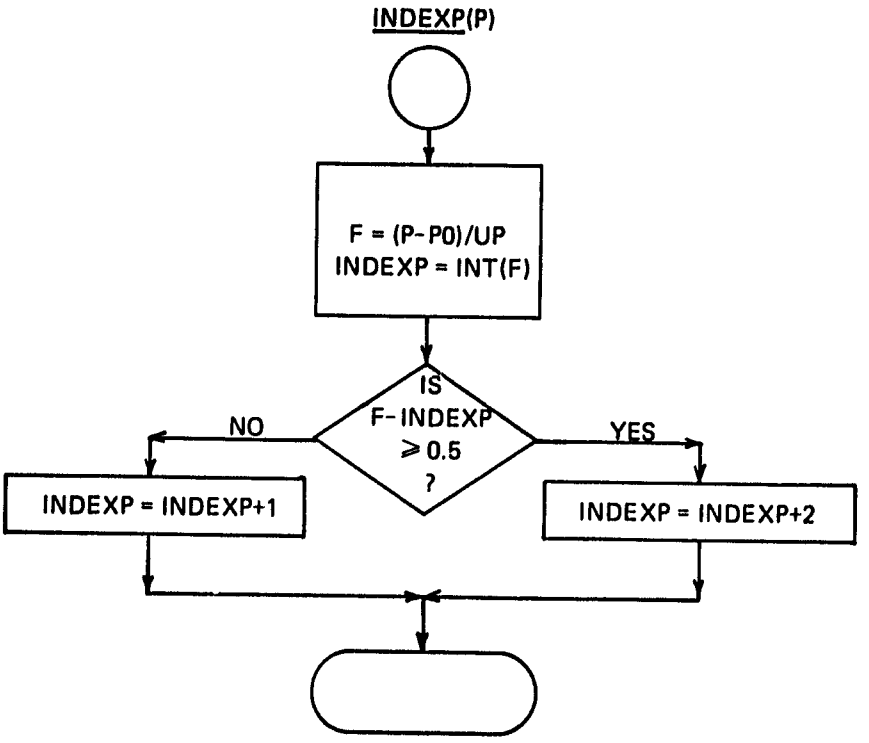
PFPPDC(PP,DC,IT)

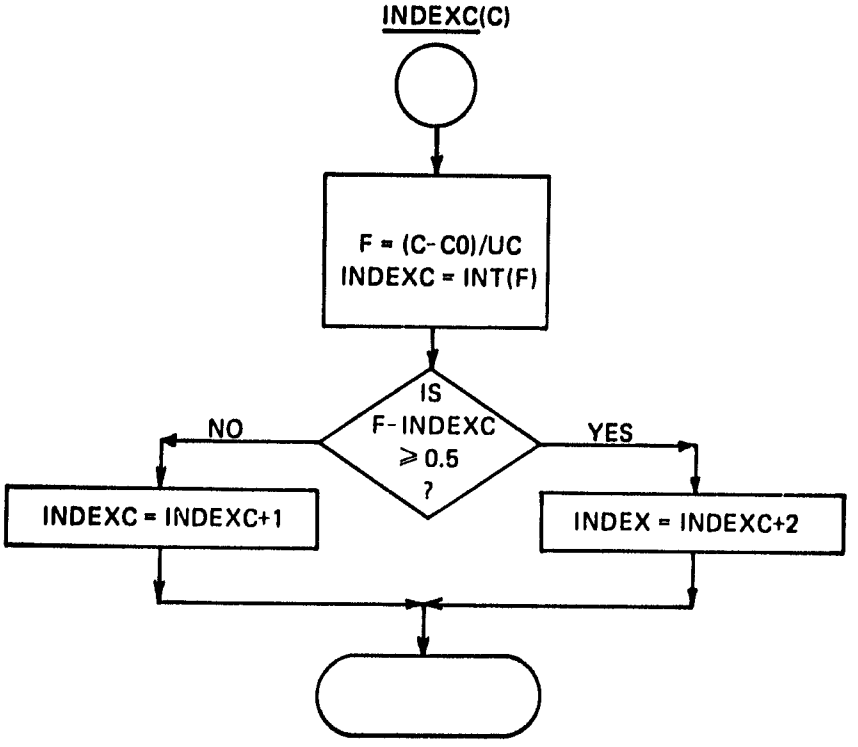
This function defines the relation between the free market price (PP) in period IT, the change of stocks (DC), and the final price (PFPPDC).

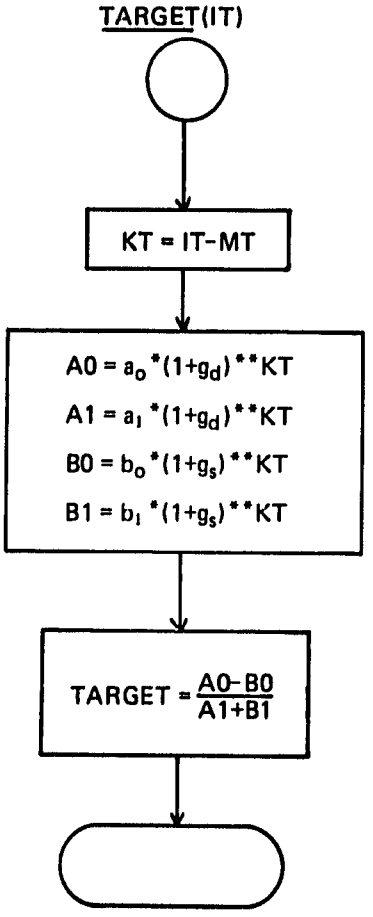
PPFEP1(E,P1,IT)

This function defines the determination of the free market price (PPFEP1) at period IT, by the lagged price (P1), and the composed disturbance (E). SD and SS are the standard deviations of the demand and supply, respectively, at period IT.

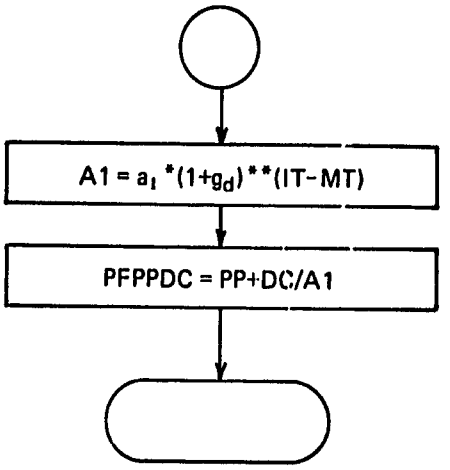
S = SD + SS is the composed standard deviation at time IT.


INDEXP(P)
F = (P-P0)/UP
INDEXP = INT(F)
IS
F-INDEXP
≥ 0.5
?
NO
YES
INDEXP = INDEXP+1
INDEXP = INDEXP+2

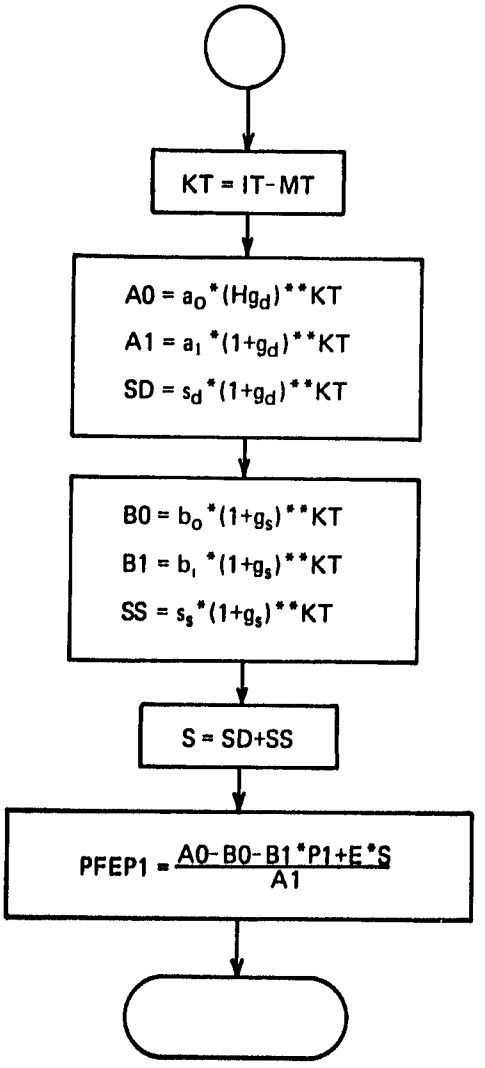

INDEXC(C)
F = (C-C0)/UC
INDEXC = INT(F)
IS
F-INDEXC
≥ 0.5
?
NO
YES
INDEXC = INDEXC+1
INDEX = INDEXC+2


TARGET(IT)
KT = IT-MT
A0 = a_o*(1+g_d)**KT
A1 = a_1*(1+g_d)**KT
B0 = b_o*(1+g_s)**KT
B1 = b_1*(1+g_s)**KT
TARGET = (A0-B0)/(A1+B1)

PFPPDC(PP,DC,IT)



PPFEP1(E,P1,IT)



REFERENCES

Bailey, W.R., F.A. Kutish, and A.S. Rojko, *Grain Stocks Issues and Alternatives – A Progress Report*, Agricultural Economic Research Report. U.S. Department of Agriculture, Economic Research Service, February 1974.

Casley, D.J., J.B. Simaika, and R.P. Sinha. "Instability of Production and Its Impact on Stock Requirements." *Monthly Bulletin of Agricultural Economics and Statistics*, Food and Agriculture Organization of the United Nations, Rome, 23 (May 1974), 1-8.

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

Food and Agriculture Organization of the United Nations. *Food Reserve Policies for World Food Security: A Consultant Study on Alternative Approaches*. Background document for the Expert Consultation on Cereal Stock Policies Relating to World Food Security, Rome, February 24-28, 1975. ESC: CSP/75/2, January 1975.

Great Plains Agricultural Council. *Stability: The Continuing Quest*, Pub. No. 74, Proceedings of Great Plains Agricultural Policy Seminar, Denver, Colorado, May 19-20, 1975.

Gustafson, Robert L. *Carryover Levels for Grains*, Tech. Bul. 1178. U.S. Department of Agriculture. Washington: U.S Government Printing Office, October 1958.

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

Schnittker, John A. "Grain Reserves – Now." *Foreign Policy*, Number 20 (Fall 1975).

Sharples, Jerry A., and Rodney L. Walker. "Analysis of Whea Loan Rates and Target Prices Using a Wheat Reserve Stocks Simulation Model." Reserve Stocks of Grain, Research Status Report Number 2, U.S. Department of Agriculture, Economic Research Service, Commodity Economics Division Working Paper, May 1975.

Tweeten, Luther, Dale Kalbfleisch, and Y.C. Lu. *An Economi Analysis of Carryover Policies for the United States Wheat Industry*, Technical Bulletin T-132. Oklahoma State University Agricultural Experiment Station, October 1971.

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

Waugh, Frederick V. *Reserve Stocks of Farm Products*. Vol. \ National Advisory Commission on Food and Fiber. Washington: U.S. Government Printing Office, August 1967.