An Analysis of Food Production ınd Grain Stock Potential in India

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AN ANALYSIS OF FOOD PRODUCTION AND

GRAIN STOCK POTENTIAL IN INDIA

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FOREWORD

The world has gone through some extreme fluctuations in grain supplies over the past two decades. In the late 1950s and early 1960s supplies were quite large and the United States built up huge stocks. Then with drought over the India subcontinent in 1966-67 higher prices for grain and greater hunger occurred. Yields then returned to normal before the large crop shortfalls in the U.S.S.R., Africa and parts of Asia in the early 1970's. Beginning with 1977, stock grain production again was large and nations were adding to stocks.

With limited buffer stocks, countries such as India suffer considerably from these large fluctuations in production. This instability impinges on consumers both through price and unavailability of food.

S. K. Ray looks at buffer stocks as a problem of food management policy in India. He proposes government grain stocks, built up during favorable production years and released in years of crop shortfalls, as a major element of food management policy. He considers the problem from the standpoint of both the nation and its individual regions. He considers that an appropriate buffer stock program should stabilize prices for farmers as well as consumers.

He analyzes the effect of weather on crop output and measures historic variations in it. He develops and applies a stochastic simulation model to evaluate the costs and benefits of a buffer stock program operating under different storage rules.

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I. INTRODUCTION

The Problem of Food Management in India

India's performance in agriculture showed a rising trend through the first four Five-Year Plans.[1] From 1950 the rate of increase in the production of food grains[2] was 2.8 percent per year, a level which adequately covered the population growth rate of 2.1 percent per annum during the corresponding time period (Randhawa, 1977).

The situation was different, however, when the performance of the individual states is considered. There was great disparity among states in production increases and in some states growth in food production did not match growth in population. Moreover, the concentration of population was extremely skewed, varying from 400 persons per square kilometer in the highly industrial state of West Bengal to 60 persons per square kilometer in the semi-arid state of Rajasthan. As a result, some states were chronically deficit in grains, some had surpluses and others were on the margin.

Also, the multiplicative effect of increased income resulting from planned development caused demand for food grains to increase faster than population growth. During this period money income rose faster than the

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[1] The first four Five-Year Plans covered the periods 1951-55, 1956-61, 1961-66 and 1969-74.

[2] Throughout this and subsequent chapters, food grains refer to both cereals and pulses. Rice, wheat, jowar (sorghum), bajra (spiked millet), maize, ragi (finger millet), barley, and small millets form the cereals group in food grains.

rate of increase in real national product, creating an inflationary pressure on the economy. Further, with a fairly inelastic demand for food grains, prices were most sensitive to the demand-supply gap. Thus, the problem on the food front became worse.

The distribution of income gains arising from planned development was not uniform among people or among regions. Because of the widespread disparities in purchasing power, it was feared that the free market mechanism would fail to assure equitable distribution of available supplies to each of the states and their various population strata at reasonable prices. Consequently, welfare considerations spurred governmental intervention.[3] Year-to-year fluctuations in the production of food grains also caused a great deal of fluctuations in their prices. Because of the lack of storage facilities farmers were not able to influence the intra-year and inter-year price fluctuations. Hence, uncertainty both plagued the income prospects of the farmers and weakened incentives to adopt new cultivation techniques.

Until 1964-65, the government's price support commitments were not particularly positive for producers. The policy was more consumer-oriented. Zoning, compulsory procurement, and credit restrictions all acted as disincentives to producers (Cummings, 1967; 1968; Herrman, 1964). Then, the two severe drought years of 1965-66 and 1966-67 brought about a decline of 31 million tons in food grains production for this two-year period

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[3] The Constitution of India puts direct responsibility on the government for the welfare of her people. Article 38 of the Constitution states: "The State shall strive to promote the welfare of the people by securing and protecting, as effectively as it may, a social order in which justice, social, economic and political, shall inform all the institutions of national life."

(Government of India, 1968b). To meet the rising demand, larger quantities of food grains were imported and distributed through fair price shops. The mounting cost of subsidies was made out of the public exchequer. In spite of concessional imports made under PL-480, the severe drought situation created a real crisis on the food front (Government of India, 1968c). This crisis exposed public policy to intense scrutiny and criticism. Concerted efforts were initiated to increase production. Agriculture in all its aspects, rather than merely food management, was given importance.

With the availability of high-yielding varieties of food grain crops and the consequent introduction of the New Agricultural Strategy into the agricultural scene after 1965, food grains production in India is now increasing at a rate faster than in earlier years. In 1976, a record harvest of over 118 million tons of food grains was recorded. However, in the present transitory stage, it is very difficult to predict what will happen on the food front in future years. Any of three distinct situations is possible: (1) demand increasing at a faster rate than production, (2) demand increasing at a slower rate than production, and (3) the two growing at the same rate. In the absence of any policy measure, real prices in the free market will then record an upward or downward trend depending upon whether the rate of growth in demand is greater than or less than the corresponding rate of growth in production. These are explosive situations, particularly in the present Indian context, and must be arrested. Evidently, policies under each of the above situations will be different depending upon the magnitude of the demand-supply gap. If production lags behind demand, need for imports and a curb on demand will become necessary. Similarly, if production grows faster than demand, export markets will have to be found or production, itself, will have to be curtailed.

However, neither the demand for nor the supply of farm products records a smooth trend. There are irregularities. Production in the agricultural sector is significantly influenced by extraneous factors, generally stochastic in nature. Again, because of the overriding importance of the agricultural sector in the Indian economy, income and hence, demand, are likely to fluctuate with fluctuations in output. Such inherent stochastic characteristics are bound to introduce instability in the price level, farm income and the quantity consumed, if the forces of demand and supply are allowed to operate freely in the market. The economic consequences of such instability affect producers' and consumers' interests and impedes overall economic growth.

Aggregate production depends upon individual investment decisions of a larger number of farm managers. If the production is to increase, income of viable farms should be such as to permit their owners to risk investment in new technology. This is of special importance in the context of the new agricultural strategy recently introduced in the country. If it is assumed *a priori* that farmers do respond to price changes, then incentive prices for their produce, including both stability and an adequate level, are necessary prerequisites for raising the level of output. Therefore, a permanent solution is to be sought through a well-formulated strategy that safeguards both producers' and consumers' interests and recognizes the probable fluctuations in production levels.

But can the producers' and consumers' interests be protected simultaneously if the system operates in an environment of uncertainty? It will be shown in the next chapter that, in general, this is not possible. A complete stabilization of farm incomes will result in price instability and hurt consumers' interests; the reverse will follow if the consumers' interests are completely protected. Evidently, the solution to these conflicting interests has to be sorted out in the realm of welfare economics with the objective of maximizing net social welfare. What policy instruments and, in particular, what operation rules can then help to attain these objectives and at what cost to the society?

We are addressing ourselves to a problem that is neither new nor confined to India. The problem has, however, assumed serious importance in recent years. India is basically a food-deficit country, but the potential for a breakthrough is now visible. To exploit this potential fully, to achieve the long-cherished desire of food self-support, rational economic policies must be pursued for farm firms to boost production However, in following any such policies, severe limitations arise because of the preponderance of a vulnerable population strata in the country. The sufferings of the underfed millions haunt the policy makers with the possibility of social unrest, and thus protection to the consumers assumes priority. Any ambitious program to safeguard both producing and consuming sectors' interest is further constrained by the prevailing inflationary situation and lack of adequate funds in the country. Moreover, unlike earlier years, food grains imports have now become costlier and a sensitive political issue.

Role of Government Stocks in Food Management

When year-to-year fluctuations in production are wide and unpredictable, price stabilization is possible only through successfully controlling demand and supply. To maintain stability at a desired level, any excess supply above the stability requirement must be procured and stored for the lean years when supply falls short of the stability requirement. Thus, an effective way to achieve stabilization is maintaining government stocks, building them during years of relative abundance and releasing them in years of relative shortages. It is only the existence of these stocks that can provide the government a position of strength to influence prices.

Past food management in India by the government did not follow this operational rule. The concern was more toward equitable distribution of whatever was available on a yearly basis; the need for stabilization over several years did not get adequate attention. The ease with which food grain was imported as a provision against future production shortfalls adversely affected the level of domestic production through the price disincentive effects and inadequate investments in agriculture. Barnum concluded that during the period 1957-64, imports of 28 million tons of PL-480 food grains depressed the path of domestic production and increased markedly the path of availability (Barnum, 1971). A similar conclusion was also reached by Manne. Consumption of the amounts available through imports, in addition to the domestic supply on yearly basis, induced a decline in domestic grain production (Manne, 1967).

The past, however, did provide opportunities to build up an adequate level of food grains stocks. If the relatively comfortable situation in the 1950s and the concessional imports under PL-480 were utilized in building up reserve stocks, the government could have reasonably buffered the sharp production shortfalls that occurred in the 1960s. The possibilities of such opportunities were pointedly illustrated through examples by Krishna (1967), Cummings (1969), and Barnum (1971). Although none of these authors examined the costs and benefits of such a program, the logic of the proposition was clearly demonstrated--to make provisions for the lean years, fat years must be trimmed above the tolerance limits and the excesses put into storage.

The importance of maintaining government stocks for food grains management operations in India can be illustrated by considering a hypothetical situation of national self-sufficiency[4] for all food grains. Assume first that demand and supply estimates are known with certainty and that they are free of fluctuations. At the all-India level, the country is self-sufficient on all items under food grains. Whatever is produced is consumed. There is no carry-over stock because domestic production is just sufficient to meet the needs with an absolute guarantee.

Even in this ideal situation of national self-sufficiency in food grains, regional problems will exist; the states, individually, will be either surplus or deficit. If inter-state trade is allowed to operate freely, grain will move from a surplus state to a deficit state only if

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[4]The phrase "self-sufficiency" is used to imply that domestic production is just sufficient to satisfy income-oriented human demand and the requirements for seed, feed and wastage.

the price in the latter is greater than the price in the former plus the cost of transportation. If the prices are deliberately kept at a uniform level across the country without other supporting measures, production in surplus states will be gradually depressed and a shortage situation will arise in the country. A certain degree of price variability over the country is, therefore, inevitable and necessary to induce movements from surplus to deficit states. If traders are allowed to operate freely, price variability among the states is likely to be at a minimum only if the movements take place along the minimum cost transportation lines. Even then, prices in some states can appear too high for low income people. The answer suggested then will be a government-subsidized distribution for the low income people. The problem in this case is one of identifying the poorer section of the community and taking adequate measures to safeguard its welfare.

Suppose now that private traders are more motivated by profit than by social responsibility. They hoard and speculate. Hoarding, it must be noted, is profitable only to the extent that the discounted expected price exceeds the current price plus the cost of hoarding. Therefore, the only way to reduce trade speculation is to increase the risk of speculation; i.e., influence the prices in such a way that traders cannot look forward to windfalls.

There are two alternatives for achieving this end. The first is direct market intervention by introducing statutory price controls. This measure will obviously put the government in total massive food grains management operation. Market imperfections will result and will affect both producers and consumers. Moreover, this approach can provide fruitful results only when price controls are rigorously implemented across the country, an accomplishment which is very difficult to achieve. In any case, it is a short-term measure which cannot continue indefinitely.

The other alternative, more practical and appealing, is to encourage a free market backed by a position of strength to influence prices through public food stocks operation. This method will increase the risk of speculation and making hoarding costlier. Government-held stocks can thus buff traders' speculation.

Food management problems become complicated as soon as perfect knowledge assumption is relaxed. Consider state-wise imbalances (instead of being fixed and known with certainty) which are random and fluctuate with certain probability distribution. Aggregate production might be above or below the total requirement. What will be the magnitude of such deviations, and when and where it will occur is not known with certainty and can at best be stated in probabilistic terms. Again, fluctuating output is likely to induce fluctuations in income and cause demand to be unstable.[5] Instability in demand and supply will cause surplus-deficit gyrations of uncertain magnitudes. Efficient and effective management of food grains will, therefore, need to take into account uncertainty in demands and supplies.

If year-to-year fluctuations are wide and unpredictable, stabilization prices, farm income and consumption objectives of the government cannot

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[5] Barnum (1971) estimated the income-generating function with food grains production and the total central and provincial government expenditure as independent variables. The estimated equation provided a very good fit.

be fulfilled by private trade alone. Private trade in India has limited storage capacity and operates on a basis of private profit maximization which does not necessarily give sufficient consideration to social and humanitarian needs.

Plan of the Study

This study is concerned with inter-year fluctuations in food grains prices and supplies in India, primarily due to weather-induced production fluctuations. The analysis includes a procedure for stabilizing these fluctuations through a food grains buffer stock program. A buffer stock, considered in an integrated food and agricultural policy framework, is defined as a stock operated by the government with the objectives of not only reducing the price fluctuations around a specified level, but also for minimizing the variability of farm income and supply availability for consumption around their growth paths. Specific issues analyzed in this study include the size and composition of the stocks and evaluation of costs and benefits of buffer stock programs.

Our approach to an investigation of the issues is experimental and is based on past experiences. Starting from a hypothetical situation of expected production equalling effective demand, we examine the probability distribution of surplus-deficit gyrations due to external shocks on a time scale. To maintain stability at the desired level, a buffer stock of certain size is determined. Stock supplies may fluctuate randomly for a fixed duration under the desired storage program but will not be allowed to exceed or fall below certain levels, i.e., we put upper and lower limits on the level of these random movements. Then we compute the probability of success for the movement to continue and cover the fixed duration and also the costs and benefits of such an action. Finally, by putting limits at different levels, we will compare the costs and benefits of the buffer stock programs of different sizes.

The more specific elements of this study are: (1) an assessment of the future growth in food grains demand and supply and (2) an estimate of the probability distribution of the food grains output fluctuations. Some theoretical considerations involved in the operation of a buffer stock program for India are first considered in the next section. The following section then provides the dimensions of India's future food problem in the context of the changing situation now occurring in the country. An assessment of the future regional imbalances in food grains is made here for the use in later chapters. The next section contains an analysis of the effect of weather on crop output. It traces the historical variations in production for estimating the size of the buffer stock. The following section includes a stochastic simulation for evaluating costs and benefits of a buffer stock program under different storage rules, with and without imports. Finally, because the buffer stock program in India is inextricably interwoven with several other aspects of the food management program, the following outlines a systems approach for food management and examines the pricing policy and the interrelated procurement and distribution program of the government.

This study has several limitations. No attempt is made to develop a generalized model of the agricultural economy relating to overall economic development. We concentrate only on the food grains sector and assume that parallel, monetary, fiscal, and other policies for price and income stability will also be pursued. Moreover, because the focus is on future years, we make assumptions about the future course of events which can be challenged. Based on current knowledge and existing technology, we attempt to provide answers as realistic as possible to these questions.

II. STABILIZATION THROUGH BUFFER STOCK OPERATION

Concept and Objectives of the Food Grains Buffer Stock Operation

Prices are determined by the forces of demand and supply under a free market mechanism. Various exogenous and endogenous factors cause the demand and supply curves to shift over time. With these shifts the corresponding changes in equilibrium conditions may introduce variations in price, farm income, and also in the level of consumption. These variations can be influenced by the operation of a buffer stock program.

Given the nature and variability conditions surrounding demand and supply, the strategy of operating a buffer stock, releasing from it and replenishing it, will depend upon the objectives of the program. Stocks can be managed by producers to maximize income, by consumers to minimize cost, or by a third party to stabilize price, farm income, and consumption. In general, these goals are not complementary and the pursuit of one may conflict with other objectives.

Our focus in this study is on inter-year fluctuations in prices, farm income, and consumption. For obvious reasons they introduce uncertainty into the consumption availability and income prospects of farmers. The Indian government's intention is to reduce this uncertainty and, in the context of food self-support determination, through operation of a food grains stock. Such buffer stocks should be maintained by the government not only to reduce price fluctuations around a specified level but also to reduce the variability of farm income and consumption from their expected growth paths. For longer-term policy planning, in the present Indian context, stocks can be manipulated to influence production, marketing, and consumption decisions in predictable, economically rational ways (Cummings, 1969).

Necessary Conditions for Price Stability

Consider a commodity whose demand and supply curves shift over time. Demand shifts because of growth in income and population while supply shifts because of growth in domestic production. There are no imports or exports of the commodity, and the demand and supply functions are of the form[1]

$$\log D_t = \log A_t - \eta \log P_t, \quad \eta > 0$$

$$\log S_t = \log B_t - \epsilon \log P_t, \quad \epsilon > 0$$

where:

D_t is the quantity demanded in year t;

S_t is the quantity supplied in year t;

P_t is the price in year t;

A_t, B_t are the intercepts; and

η and ϵ are demand and supply elasticities, respectively.

In equilibrium:

$$\log D_t = \log S_t$$

$$\text{or} \quad \log A_t - \eta \log P_t = \log B_t + \epsilon \log P_t$$

$$\log P_t \, (\eta + \epsilon) = \log A_t - \log B_t$$

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[1]The analysis that follows is not affected by the form of demand and supply curves.

differentiating with respect to time t

$$\frac{1}{P_t} \cdot \frac{dP_t}{d_t} (\eta + \epsilon) = \frac{1}{A_t} \cdot \frac{dA_t}{d_t} - \frac{1}{B_t} \cdot \frac{dB_t}{d_t}$$

if $\frac{1}{P_t} \frac{dP_t}{d_t} = P_t, \frac{1}{A_t} \frac{dA_t}{d_t} = \dot{A}_t$

and $\frac{1}{P_t} \frac{dP_t}{d_t} = \dot{B}_t$, then

$$\dot{P}_t (\eta + \epsilon) = \dot{A}_t - \dot{B}_t$$

$$\dot{P}_t = \frac{\dot{A}_t - \dot{B}_t}{(\eta + \epsilon)} \qquad (1)$$

The demand function can be written as $\log Q_t = \log A_t - \eta \log P_t$, $\eta > 0$ where A_t is the equilibrium quantity, differentiating this with respect to time t,

$$\frac{1}{Q_t} \frac{dQ_t}{d_t} = \frac{1}{A_t} \frac{dA_t}{d_t} - \eta \frac{1}{P_t} \frac{dP_t}{d_t}$$

$$\dot{Q}_t = \dot{A}_t - \eta \dot{P}_t \qquad (2)$$

where:

$$\dot{Q}_t = \frac{1}{Q_t} \frac{dQ_t}{d_t} ;$$

$\dot{A}_t$, $\dot{P}_t$ are same as before.

Substituting the value of $\dot{P}_t$ from equation (1) in the equation (2):

$$\dot{Q}_t = \dot{A}_t - \eta \frac{\dot{A}_t - \dot{B}_t}{(\eta + \epsilon)}$$

$$= \dot{A}_t - \frac{\eta}{\eta + \epsilon} (\dot{A}_t - \dot{B}_t) \qquad (3)$$

Farm income (R_t) can be written as

$$R_t = P_t \bullet Q_t$$

$$\log R_t = \log P_t + \log Q_t$$

differentiating with respect to time t,

$$\frac{1}{R_t} \bullet \frac{dR_t}{d_t} = \frac{1}{P_t} + \frac{1}{Q_t} \quad \frac{dQ_t}{d_t}$$

$$\dot{R}_t = \dot{P}_t + \dot{Q}_t \tag{4}$$

where $\dot{R}_t = \frac{1}{R_t} \frac{dR_t}{d_t}$

Substituting the values of $\dot{P}_t$ and $\dot{Q}_t$ from the equations (1) and (3), respectively, in equation (4):

$$\dot{R}_t = \frac{\dot{A}_t - \dot{B}_t}{(\eta + \epsilon)} + \dot{A}_t - \frac{\eta}{\eta + \epsilon} (\dot{A}_t - \dot{B}_t)$$

$$= \frac{1}{(\eta + \epsilon)} [\dot{A}_t - \dot{B}_t + \eta \dot{A}_t + \epsilon \dot{A}_t - \eta \dot{A}_t + \eta \dot{B}_t]$$

$$= \frac{1}{(\eta + \epsilon)} [(1 + \epsilon) \dot{A}_t - (1 - \eta) \dot{B}_t] \tag{5}$$

Thus, $\dot{P}_t$, $\dot{Q}_t$, and $\dot{R}_t$ give rates of change in price, quantity, and farm income, respectively.

Year-to-year changes in price will thus record an upward or downward trend accordingly as $\dot{A}_t \lesseqgtr \dot{B}_t$ and the steepness of this trend will depend upon the magnitudes of $\dot{A}_t$, $\dot{B}_t$, and the elasticities of demand and supply. Given the rate of change in demand and supply, price will increase at a slower rate for elastic than for inelastic demand and supply curves. Again, depending upon the rate of change in demand and supply and their corresponding elasticities, the level of consumption will record a trend. If demand increases at a faster rate than supply, the consumption level will grow at a slower rate than demand; the reverse will be the case if supply grows faster than demand. Similarly, farm income will record an upward or downward trend accordingly as $(\dot{A}_t/\dot{B}_t) \lesseqgtr [(1 - \eta)/(1 - \epsilon)]$.[2] Evidently, $(\dot{R}_t)_{\eta>1} > (\dot{R}_t)_{\eta=1} > (\dot{R}_t)_{\eta<1}$ and therefore, for a given rate of change in demand and supply, the rate of change in farm income will be larger for the elastic than for inelastic demand.

Growth in demand and supply from one period to the next, however, seldom records a uniformly constant rate. These rates fluctuate and thus cause fluctuations in price, farm income, and consumption around their expected levels. The magnitudes of these variations are given by

$$V(P_t) = \frac{1}{(\eta + \epsilon)} \; 2[V(\dot{A}_t) + V(\dot{B}_t) - 2 \text{ Cov } (\dot{A}_t, \dot{B}_t)]$$

$$V(Q_t) = \frac{1}{(\eta + \epsilon)} \; [\epsilon^2 V(\dot{A}_t) + \eta^2 V(\dot{B}_t) + 2\eta\epsilon \text{ Cov}(\dot{A}_t, \dot{B}_t)]$$

$$V(R_t) = \frac{1}{(\eta + \epsilon)} \; 2[(1 + \epsilon)^2 V(\dot{A}_t) + (1 - \eta)^2 V(\dot{B}_t)$$
$$-2(1 + \epsilon)(1 - \eta) \text{ Cov } (\dot{A}_t, \dot{B}_t)]$$

where V(x) denotes the variance of the variable 'X' and Cov (X, Y) denotes the covariance between the variables X and Y.

2

$$\dot{R}_t = \frac{1}{(\eta + \epsilon)} [(1 + \epsilon)\dot{A}_t - (1 - \eta)\dot{B}_t)]$$

from this

$$\frac{\dot{A}_t}{\dot{B}_t} = \frac{(1 - \eta)}{(1 + \epsilon)} \text{ as } R_t \lesseqgtr 0.$$

Consider the following three cases of (1) positively correlated, (2) uncorrelated, and (3) negatively correlated changes in demand and supply. These are equivalent to saying (1) Cov $(\dot{A}_t, \dot{B}_t) > 0$, (2) Cov $(\dot{A}_t, \dot{B}_t) = 0$, and (3) Cov $(\dot{A}_t, B_t) < 0$. Then, irrespective of the nature of demand and supply curves

$$V_1(\dot{P}_t) < V_2(\dot{P}_t) < V_3(\dot{P}_t)$$

$$V_1(\dot{Q}_t) > V_2(\dot{Q}_t) > V_3(\dot{Q}_t)$$

where V_1, V_2 and V_3 are the variances when Cov $(\dot{A}_t, \dot{B}_t) > 0$, Cov $(\dot{A}_t, \dot{B}_t) = 0$, and Cov $(\dot{A}_t, \dot{B}_t) < 0$, respectively. For farm income, however, $V_1(\dot{R}_t) > V_2(\dot{R}_t) > V_3(\dot{R}_t)$ if demand is elastic $(\eta < 1)$ and $V_1(\dot{R}_t) < V_2(\dot{R}_t) < V_3(R_t)$, if demand is inelastic $(\eta < 1)$. Also, if the growth in demand is steady, i.e., $V(\dot{A}_t) = 0$, then $V(\dot{R}_t) = 0$ for $\eta = 1$. Thus, a demand curve with unit elasticity will always provide a fluctation-free growth curve for farm income if the growth in demand is steady.

Necessary conditions for price stabilization through stocks can now be stated. As a long-term policy instrument, a buffer stock alone will fail to stabilize prices unless the expected rate of growth in demand and domestic supply is equal. If demand grows faster than supply and prices are to be stabilized through stocks there will be frequent runs on stocks and they will soon be exhausted. If supply grows faster than demand and prices are kept steady, there will be frequent buildup of stocks and they may soon exceed the country's optimum storage and capacity. It is only when the expected growth rates in demand and supply are equal that buffer stocks can be thought of as a useful mechanism to moderate excess price fluctuations. For, if $E(\dot{A}_t) = E(\dot{B}_t) = r$, then only $E(\dot{P}_t) = 0$ and $E(\dot{Q}_t) = E(\dot{R}_t) = r$; where $E(x)$ stands for expected value of x. Under such a situation, price will fluctuate throughout the period around a particular value while farm income and consumption will grow with fluctations around their respective growth curves. In particular, if $r = 0$, then throughout the period the variables P_t, Q_t and R_t will not record any upward or downward trend but fluctuate around their respective initial values. Whether in the coming years food grains demand and supply in India will grow at the same rate is difficult to predict, but there is little doubt that both will be significantly greater than zero and record fluctuations. The stabilization objectives can thus be attained if the buffer stock programs along with other policy measures are operated so that throughout the period the growths in demand and supply are approximately kept under equilibrium, and $V(\dot{P}_t)$, $V(\dot{Q}_t)$ and $V(\dot{R}_t)$ are reduced.

Evidently, success of the buffer stock program will depend upon the mean price level around which stabilization is desired. In general, this should be close to the price in the free market. If the mean price is deliberately fixed at a lower level than would prevail in the free market, a shortage and(or) scarcity situation will develop; on the other hand, if the mean price is supported at a higher level, the country will be burdened with a huge stockpile. And, whatever else is done during the shortage or surplus situation (such as rationing, a grow-more-food campaign, etc.), the thing that can bring demand and supply under equilibrium over a finite number of steps, if they tend to grow at different rates, is a shift in the mean price level around which stabilization is sought. If a shortage develops because of slow growth in production, a mean price fixed at a higher level will curb demand and boost production; if the situation is one of plenty because of high growth in production, a mean price fixed at a lower level will discourage production and encourage consumption.

Conditions for Buffer Stock Operation

Wtih the expected growth rate in demand and domestic supply equal, the success of a buffer stock program will depend upon the nature and variability of the demand and supply curves. With linear demand and supply functions such as

$$D_t = A_t - aP_t, \quad a > 0$$

$$S_t = B_t + bP_t, \quad b > 0$$

which change by parallel shifts around their respective mean positions, $\bar{A} = (\sum_1^T A_t)/T, \bar{B} = (\sum_1^T B_t)/T$. The total income R_o, over a period of length T is

$$R_o = \sum_1^T P_t Q_t$$

$$= \frac{T}{(a+b)^2} [b\bar{A}^2 + (a - b)\bar{A}\,\bar{B} - a\bar{B}^2] + T \text{ Cov } (P_t, Q_t)$$

Sundrum (1971) showed that if a self-liquidating buffer-stock program is carried out over the period of length T (stock Y_t is released or withdrawn such that $\sum_1^T Y_t = 0$) with the objective to stabilize price, then under such a scheme the stabilized price will be

$$P_s = \frac{\bar{A} - \bar{B}}{a + b} = \frac{1}{T} \sum_1^T P_t$$

and the total farm income R_s under the stabilized price P_s will become

$$R_s = R_o - T \operatorname{Cov}(P_t, Q_t)$$

$$= R_o - \frac{T}{(a + b)^2} [b\, V(A_t) - a\, V(B_t) + (a - b) \operatorname{Cov}(A_t, B_t)]$$

Now, $R_s \lesseqgtr R_o$ accordingly as $\operatorname{Cov}(P_t, Q_t) \lesseqgtr 0$, i.e., accordingly as the weighted price $(\sum_1^T P_t Q_t)/(\sum_1^T Q_t) \gtrless$ average price $(\sum_1^T P_t)/T$. Thus, a completely stable price over a period of length T will be profitable to the producers only if the stable price thus determined (which is the average price $(\frac{1}{T} \sum_1^T P_t)$ is higher than the weighted price (which is the average price for the entire quantity over the period). In particular, $R_s > R_o$ when $V(B_t) = 0$ and $R_s > R_o$ when $V(A_t) = 0$. The level of consumption will, however, fully fluctuate unless the demand is stable. Similarly, with demand and supply curves of constant elasticity which change over time, Sundrum (1971) showed that if a self-liquidating buffer stock program is carried out for price stabilization, $R_s < R_o$ for $b > 0$ and $0 < a < 1$.

The implications of the above aspects of operating a stock program are now clear. If the instability in price, farm income, and consumption is due entirely to unstable demand, then a buffer stock program for complete price stabilization can completely stabilize farm income but not consumption; the latter will fluctuate to the extent of changes in demand at the stabilized price. In particular, if the instability in demand is due to the income effect only, then operation of the price stabilization stock program would require augmentation of consumption in the years of good demand and restriction in the years of poor demand (i.e., feed the boom years by starving the depression years). Boulding (1965) argues that this is most undesirable because, "The stability of one element of the economy--the income of the producers of the particular commodities stabilized--would be obtained only at the cost of unstabilizing what may be a much more important element in the economic, consumption."

Buffer stocks operation can be justified if supply fluctuations are more pronounced than demand fluctuations. In this case, also, there will be some undesired consequences unless demand and supply elasticities satisfy some specific conditions. For a stable demand function, $f(P_t)$, with constant elasticity, η, and a variable supply function, $g(P_t) + B_t$, with a constant elasticity, ϵ, at its average position, Sundrum (1971) showed that if a fraction α of the supply shift is bought or sold by the buffer stock agency then the variabilities of price and farm income over time are given by[3]

$$V(P) = [\overline{P}(1 - \alpha)/\overline{Q}_t(\eta + \epsilon)]^2 \, V(B_t)$$

$$V(R) = [\overline{P}(\alpha\epsilon + \eta + \alpha - 1)/(\eta + \epsilon)]^2 \, V(B_t)$$

Thus, compared to the original situation of no stabilization ($\alpha = 0$)
a) completed price stabilization ($\alpha = 1$) will reduce the variability in farm income if η (1 -)/2; and b) complete farm income stabilization $[\alpha = (1 - \eta)/(1 + \epsilon)]$ will reduce the variability in price if $\eta < 1$.

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[3]These are derived from

$$f(P_t) = \overline{Q} - \eta \cdot \frac{\overline{Q}}{\overline{P}} \cdot (P_t - \overline{P})$$

$$g(P_t) = \overline{Q} + \epsilon \cdot \frac{\overline{Q}}{\overline{P}} \cdot (P_t - \overline{P})$$

where $\overline{Q}$ is the average quantity, $\overline{P}$ is the average price, Q_t is the quantity in year t, and P_t is the price in year t.

continued....

If $\eta > 1$, then for complete farm income stabilization the buffer stock agency must increase both gluts and scarcities (since α is negative) and thereby increase variability in price and consumption. Again with $1 > \eta > \frac{1 - \epsilon}{2}$, the purchasing and selling operations during good and bad harvest years for complete price stabilization will increase the variability in farm income. Only if $\eta < \frac{1 - \epsilon}{2} < 1$, the purchasing and selling operations of the buffer stock agency during years of bumper and poor harvest will simultaneously reduce the variability in price, farm income, and consumption.

Several observations can be made from the above results. First, for a meaningful buffer stock program the demand and supply functions must be inelastic. Second, simultaneous complete stabilization of price, farm income, and consumption through buffer stock operation is not possible;

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and $f(P_t) + \alpha B_t = g(P_t) + B_t$ which provide

$$Q_t = \overline{Q} + [(\alpha\epsilon + \eta)/(\eta + \epsilon)]\ B_t$$

$$P_t = \overline{P} - (P/Q)\ [(1 - \alpha)/(\eta + \epsilon)]\ B_t$$

and R_t = income in year t

$$= P_t\ Q_t$$

$$= \left\{\overline{P} - (\overline{P}/\overline{Q})\ \{(1 - \alpha)/(\eta + \epsilon)\}\ B_t\right\} \left\{\overline{Q} + \{(\alpha\epsilon + \eta)/(\eta + \epsilon)\}\ B_t\right\}$$

$$= \overline{P}\ \overline{Q} + \overline{P}\ \{(\alpha\epsilon + \eta)/(\eta + \epsilon)\}\ B_t - \overline{P}\ \{(1 - \alpha)/(\eta + \epsilon)\}\ B_t$$

$$- (\overline{P}/\overline{Q}) \left\{\frac{(1 - \alpha)\ (\alpha\epsilon + \eta)}{(\eta + \epsilon)^2}\right\} B_t^2$$

dropping the last term from the equation we get

$$R_t = \overline{P}\ \overline{Q} + \overline{P}\ \ [(\alpha\epsilon + \eta + \alpha - 1)/(\eta + \epsilon)\ ]\ B_t$$

fluctuations in them can only be reduced. Finally, since for $\eta<1$, $\alpha = \frac{1-\eta}{1+\epsilon}$ is also less than 1, it follows that the quantum of sale and purchase for complete farm income stabilization will be always less than for complete price stabilization for which α must be 1.

Thus, the buffer stocks program advocated here for reducing the variability in price, farm income, and consumption will be meaninful only if (i) the basic cause of instability in them is due to fluctuating output and (ii) the demand and supply curves are inelastic. When these conditions are satisfied, the extent of relative stabilization of price and farm income will depend upon the operational strategy of the buffer stock agency. Evidently, complete stabilization of both price and farm income is not possible and, therefore, the operational strategy of the buffer stock agency will be to choose α such that the variability in price and farm income are reduced to desired levels.

Justification for a Buffer Stocks Program: Some Empirical Evidence

Some empirical results which follow seem to justify the operation of a stabilization stock program in India. For this purpose, the causes of fluctuations in past food grains prices in India (1952 through 1968) are first analyzed with the help of some single equation models.[4]

The past grain situation in India has been one of chronic food shortages. While demand increased rapidly, domestic supply was erratic due to vagaries of weather and continuously lagged behind demand. The availabilities of different items under food grains recorded wide fluctuations and nonrecorded any noticeable upward trend. On the other hand,

[4] For details, see Ray (1972).

both real income and money supply increased steeply with corresponding repercussions on individual items of demand.

Some economists (Shenoy, 1963) believe that the rise in prices was due to the effects of PL-480 counterpart funds on the country's money supply. This suspicion has some credence in the sense that the upward trend in money supply almost coincided with the imports under PL-480. The controversy is confounded by the operation of another factor. This is the inflationary effect of large-scale deficit financing by the government to meet plan expenditures.

Because the rise in demand also is reflected in the country's money supply, and the money supply, subject to some considerations of velocity behavior, is an indicator of demand, inclusion of the money supply as an independent variable in the price equation seems appropriate. Further, since the past was a period of chronic food grain shortages and the government had very scarce stocks with which to influence prices, whatever quantities were made available to the public were consumed straightaway. Availabilities for consumption were, therefore, likely to have some functional relationship with prices.

Simple reasoning would lead to the belief that current prices are governed by current availabilities. However, there was some attempt by the government to improve upon a minimum quantity of food grains to the people over time. This concern, expressed through domestic production and imports, probably created expectation for food grains supplies and, hence, on prices. The actual change brought about in supply was, however, only a partial realization of the expected change due to a fall in domestic production, difficulty in imports, or both. Thus, an appropriate single equation model to explain the price behavior of food grains is likely to have the following functional form :

$$P_t = f(M_t, S_t, S_{t-1})$$

where:

P_t is the price index (calendar year, 1952-53 = 100);

M_t is the money supply in year t (billion rupees per year); and

S_t is the per capita availability of food grains in year t (kg/year).

A linear relationship of the above functional form when fitted to the data 1952 through 1968 (Table 1) for food grains as a whole, cereals as a group, and rice separately, provided the following results.[5]

	Equation	R^2	D-Statistic
Food grains:	$P_t = 299.80 + \underset{(0.13)}{3.23^*M_t} - \underset{(0.16)}{0.75^*S_t} - \underset{(0.16)}{1.04^*S_{t-1}}$	0.98	2.12
Cereals:	$P_t = 277.32 + \underset{(0.11)}{3.40^*M_t} - \underset{(0.17)}{0.73^*S_t} - \underset{(0.26)}{1.24^*S_{t-1}}$	0.98	2.17
Rice:	$P_t = 190.32 + \underset{(0.13)}{2.81^*M_t} - \underset{(0.27)}{1.14^*S_t} - \underset{(0.26)}{1.27^*S_{t-1}}$	0.98	2.15

(Figure in parentheses denotes standard error. Significance at 5 percent level is denoted by *.)

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[5]Zero-order correlation coefficients between the independent variables in each of the above equations are not significant.

Table 1. Reported and estimated prices of food grains as a whole, cereals as a group, and rice - 1952 to 1968[a]

Year	Money Supply (Rs. bil.)	Per Capita Availability (Kg. year)			Price index (Annual Average, 1952-53=100)					
					Reported			Estimated		
		Food Grains	Cereals	Rice	Food Grains	Cereals	Rice	Food Grains	Cereals	Rice
1951	-	143.8	121.7	58.0	-		-	--	-	-
1952	18.0	140.4	118.8	58.0	99.0	99.0	100.0	103	101	101
1953	18.3	150.3	127.4	60.5	100.0	100.0	102.0	100	100	99
1954	19.6	166.7	141.3	70.8	81.0	84.0	86.0	82	83	88
1955	22.2	161.7	135.8	65.6	70.0	73.0	76.0	76	79	88
1956	23.4	157.3	131.6	68.7	90.0	92.0	93.0	89	93	94
1957	24.1	162.9	136.7	70.4	99.0	102.0	104.0	92	97	90
1958	25.3	148.9	127.6	60.1	103.0	105.0	108.0	100	101	103
1959	27.2	170.6	143.3	69.7	104.0	104.0	102.0	105	108	111
1960	28.7	163.7	139.8	68.5	103.0	105.0	109.0	92	96	104
1961	30.5	170.4	145.3	73.3	100.0	102.0	105.0	100	102	105
1962	33.1	168.5	145.8	74.2	105.0	106.0	109.0	103	104	106
1963	37.5	161.0	139.3	67.6	111.0	112.0	122.0	125	123	124
1964	40.8	164.3	145.8	73.2	138.0	134.0	133.0	141	137	136
1965	45.3	173.0	150.7	75.5	149.0	145.0	135.0	145	141	138
1966	49.5	146.7	129.6	58.5	167.0	165.0	166.0	169	165	167
1967	53.5	144.5	130.2	55.5	219.0	207.0	201.0	211	204	203
1968	57.8	166.6	146.2	66.6	207.0	205.0	211.0	211	206	206

[a]Source: Basic data are from Bulletin on Food Statistics, Ministry of Food, Agriculture, Community Development and Cooperation, April, 1969.

All the coefficients in the above equations are highly significant and are of appropriate signs.[6] Also, consistent with the observations made by Mellor and Dar (1967), and Divatia and Pani (1968), the weight of the lagged availability on prices in the above equations is higher than the corresponding weight of the current availability.

The causes of price fluctuations are probably much more complicated than the simple relationships derived here. Comparisons of the estimated and reported prices, however, provide sufficient confidence on the estimated equations. The derived relationships predict prices very well in as much as the estimated prices closely fit the historical record of prices.

The implicit average price flexibility and price elasticity coefficents derived from the estimated equations are as follows:[7]

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[6] Per capita availability used in the estimates is based on the total of net domestic production available for human consumption, imports, and change in government stock. Per capita availability thus differs from the actual per capita consumption because the latter also includes changes in private stocks on which no data are available in India.

[7] Following Mellor and Dar (1967), these are derived as follows:

$$P_t = bA^*_t \text{ and } (A_t - A_{t-1}) = r(A^*_t - A_{t-1})$$

where for food grains $A_t^* = S_t^*$, $A_t = S_t$ and $A_{t-1} = S_{t-1}$

which in reduced form becomes $P_t = \frac{b}{r} A_t + \frac{b(r-1)}{r} A_{t-1}$

Thus, for food grains $b/r = 0.75$; $b(r-1)/r = -1.04$ and, therefore, $\underline{r} = 2.39$ and $\underline{b} = -1.79$. With average value of P_t and A_t for food grains at $\overline{P}_t = 120.17$ and $\overline{A}_t = 159.85$.

$$\overline{A}_t \cdot \overline{P}_t \frac{dP_t}{dA_t} = -2.38 \text{ and } (\overline{P}_t/\overline{A}_t) \frac{dA_t}{dP_t} = -0.42$$

	Price Flexibility	Price Elasticity
Food Grains	-2.38	-0.42
Cereals	-2.24	-0.45
Rice	-1.32	-0.75

The estimated elasticity coefficients are all less than one and the demand functions can thus be considered as price inelastic. Similar results were also obtained by Herrman (1964), Thamarajakshi (1970a), and Mellor and Dar (1967).

The estimated equations provide an opportunity to examine the causes of fluctuations in past food grains prices. For this purpose, per capita availabilities in the respective price equations are kept constant at their mean levels and money supply variable allowed to take recorded values. The estimated prices thus obtained recorded more or less smooth upward trends. Thus, while the upward trends in major food grains prices were largely due to steadily rising demand and various fiscal and monetary measures taken by the government, price fluctuations as such were mostly because of changes in quantity supplied. The slight variations in the year-to-year rise in demand were mostly because of fluctuating income effect. However, this type of instability in demand can be corrected by following suitable monetary and fiscal measures.

An impressive amount of empirical evidence is now available to indicate farmers' output response to prices in India. However, there is general agreement that the price responsiveness of producers in marketing their output is very weak in India, if not zero.[8] By and large, Indian

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[8] For references see Krishna (1962, 1963, 1967a); Falcon (1962, 1964); Bupta and Majid (1962); Hopper (1968); Narain (1965); Venkataramanan (1958); Randhawa (1963); Krishna and Rao (1968); Cummings (1968); Lele (1967, 1968); and Kulkarni (1965).

agriculture is still functioning close to a subsistence level. The majority of farmers in the country traditionally grow one or two food crops and some other items mainly for family consumption. To meet cash obligations, they are compelled to dispose of most of their marketable surplus immediately after the harvest at whatever price prevails at the time. Lack of holding and(or) storage capacity cause them to be price insensitive.

Thus, it appears that although demand for food grains in India is relatively stable and the price is inelastic, supply is erratic and somewhat price insensitive in the short run. This suggests that a buffer stock program can have advantages for stabilizing price, farm income, and the consumption level.

Economics of the Buffer Stock Operation

Given that the conditions are satisfied for the buffer stock program, the operational strategy in the absence of any financial constraints will be as shown in Figure 1 (Boulding, 1965; Heady, 1962).

The demand curve DD' is stable and inelastic while the market supply curve is completely inelastic and shifts between OT and OT' because of output fluctuations. With normal supply at OM, price in the market rules at OS, providing a normal farm income of OMRS. EE' is a unit elasticity demand curve through R and, therefore, farm income measured at any point on it is always equal to OMRS. Without any buffer stock program, price will fluctuate between ON, ON' and farm income between OTPN, OT'P'N'. If stocks are now operated to stabilize price at OS (MT released when output is OT or MT' withdrawn when output in OT'), farm income will deviate from its normal by the amount SVQL or SV'Q'L'. A buffer stock program in this case will, year after year, provide the consumers a stable supply at a stable price and compensate the losses which the farmers will incur during poor crop years by providing more income during good crop years. If, however, the objective is to completely stabilize farm income, stock QK or QK' will be released to or withdrawn from the market to maintain the farm income at the level OMRS; but then price and consumption will not remain stable; price will fluctuate between OL, OL', and consumption between LK, L'K'.

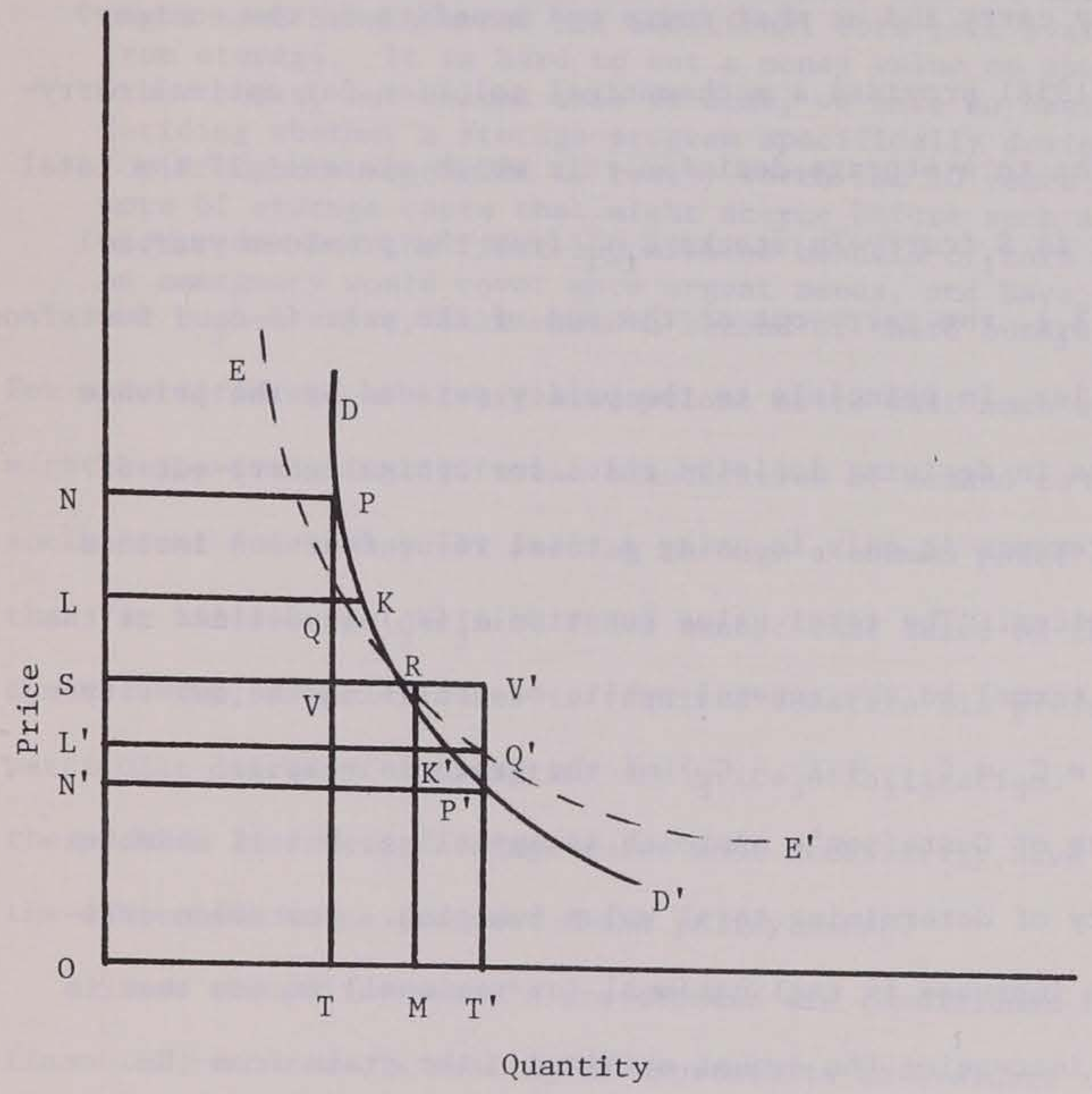

Figure 1. Operational strategy of the buffer stock program

However, the fluctuations in production do not follow a time-ordered symmetrical pattern. They are random. It will be shown in a later chapter that the major cause of production fluctuations in India is the erratic behavior of the monsoon currents. Under such an uncertain situation, the desired level of stabilization will depend upon the stockholding capacity of the buffer stock agency. Since external aupplies are, in general, to be ruled out in the context of food self-support objective, the agency must build up an adequate level of food grains stock from internal sources to safeguard against future production shortfalls. But how much stock should the agency carry and at what costs and benefits to the society?

Gustafson (1958) provided a mathematical solution for optimal carry-out stocks leading to a storage decision rule which states: If the total supply in year t is S_t (carry-in stocks C_{t-1} from the previous year t-1 plus production X_t), the carry-out at the end of the year is C_t. Gustafson's approach is similar in principle to the policy pursued by the private storage operators in deriving decision rules for optimal carry-out of stocks; the difference is only in using a total value function instead of the market prices. The total value function $\delta_t(Y_t)$ is defined as the value (in money terms) to the general public of utilizing the quantity Y_t (which is $S_t - C_t = C_{t-1} + X_t - C_t$) of the grain in year t.

The elegance of Gustafson's approach is appealing, but it stumbles on the difficulty of determining total value function. Gustafson estimated it as "the increase in real national (or regional) income that is attributable to increasing the amount utilized of the grain from the minimum value of Y(Y min) to Y itself, when other productive capacity is given." Although acknowledging it as a crude approach, he argued that, "Even an approximate value function is certainly likely to be better than one which ignores the problem of evaluation."

In 1953, Fox (U.S. Congress, 1964; the author was anonymous in this report) drew upon Gustafson's preliminary results to derive several alternative storage rules for the corn price support program in the United States. Fox said:

> ". . . Some economists feel that this rise in the market price of corn does not reflect the full extent of the harm or social costs resulting from a drought, some of which might have been averted had additional corn been available from storage. It is hard to set a money value on these other costs, but unless this is done, we have no basis for deciding whether a storage program specifically designed for drought emergencies is really worth the 10 years or more of storage costs that might accrue before such a drought occurred. And the first 100 million bushels of corn in such an emergency would cover more urgent needs, and have greater per bushel value, than would a second or third hundred million."

Fox made different arbitrary assumptions as to what such social costs might be by assigning different elasticities of demand to the marginal social cost functions, all passing through a common point and observed that "in all storage decision rules except that based on the free-market demand curve, a policy maker is required to state his preferences for a particular degree of consumption and price stabilization." The crux of the problem lies here; storage rules must necessarily have to come from the subjective value judgment of the policy maker.

Since the policy maker's preferences are conditioned by available financial resources, a meaningful approach is to evaluate the social benefits (or costs) for achieving a desired level of stabilization at varying levels of storage capacity and then choose among those the one for which the marginal social benefits (or costs) is maximum (or minimum). This was essentially what Reutlinger (1971, 1976) suggested for evaluating buffer stock programs. Given the probability distribution function of the output, market demand function, cost of storage, discount rate and the storage rule expressing the level of stabilization desired by the policy maker, Reutlinger computed several benefit indices and their variability for a given level of storage capacity. To compare the relative benefits and costs for achieving different levels of stabilization, the exercise is then repeated for different storage rules and at different levels of storage capacity.

It is apparent that the most crucial aspect of operating Reutlinger's stochastic simulation model is the generation of sequentially ordered production data series which, probably for convenience, Reutlinger generated from a triangular probability distribution. Evidently, the simulation results will be more realistic if the production data sets are generated from the probability distribution estimated from a historical analysis of output fluctuations. We propose this in chapter four.

In the following chapters, we focus on issues exclusively related to a stabilization stock program for India covering the last quarter of this century.

III. DIMENSIONS OF THE FUTURE FOOD PROBLEMS IN INDIA

Regional imbalances in food grains demand and supply, covering the years 1986 and 2001, are estimated in this chapter under the assumption of an overall food self-support plan for all food grains. The estimates are made as a base for analyzing and estimating the different components of a food grains stabilization stock program for India in the remaining chapters.

Prospects of Food Self-Support in India

With the availability of high-yielding varieties of grains and the consequent introduction of the New Agricultural Strategy,[1] India has significantly improved food grains production performance in recent years. The achievements of the new agricultural strategy since 1965 is impressive enough to suggest that the country is on the way toward achieving a higher trend rate of food grains production. The potential of the high-yielding varieties is favorable and the problems identifiable and correctable. If the present trend is any indication, the possibilities are likely to increase over time. However, there is now a big gap between performance and potentials created by the new agricultural strategy.[2] Closing this

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[1]For a detailed discussion on the "New Agricultural Strategy," see Cummings, Herdt and Ray (1968); Cummings and Ray (1969a, 1969b); and Hendrix (1970). They also provide fairly exhaustive references of recently published papers on the topic.

[2]For example, at the present fertilizer-food grain price ratio, a significant increase in production can be obtained by increasing the current rate of fertilizer application on high-yielding varieties.

gap itself will enable the country to attain a much higher growth rate in production.

In recent years the country witnessed a spectacular increase in wheat production made possible with the introduction of readily available wheat technology. Adaptive improvements made by Indian researchers over the imported technology now provide enough confidence to meet the country's demand for wheat. The performance is less spectacular in the case of rice which accounts for more than 40 percent of the country's total food grains production. Unlike wheat, imported technology is unlikely to provide a solution for increasing rice production because its success depends on many environmental factors. Moreover, sophisticated managerial skill is involved in its production process. Indian breeders are still struggling to evolve suitable strains of rice for different soil-climatic regions of the country. With the recent introduction of some high-yielding varieties of rice and the possibility of further breakthroughs in developing new strains, there is hope for an adequate rice supply in the future.

The most important factor that will influence the future growth rate in food grains production in India is probably the water supply. For most parts of the country the natural supply of water in the form of rain and river water is neither dependable nor adequate. The evapotranspiration demands exhibit pronounced seasonality in India and is markedly out of phase with the highly seasonal distribution of rainfall (Russell and Brinegar, 1969).

Sen (1970) points out that

"Even if all the surface and groundwater potential in the country is exploited (and this may take about three decades), only 82 million hectares will get assured irrigation throughout the year. Thus, out of a total of 194 million hectares of cultivable area in the country, about 112 million hectares will continue to depend wholly and another 20 to 30 million hectares partly on rainfall."

With this somewhat disturbing prospect about water supply, an accelerated growth rate in food grains production might be difficult for India to attain unless increasing emphasis is given to efficiency water management.[3]

The debate on Indian agriculture is now focused on a new strategy and its potentials to provide a long-term solution to the country's food problem. Opinion about the future has varied from one of continuing food shortages to one of a comfortable situation of excess supplies. It is probably too early to speak with confidence about attaining a higher long-run growth in food grains production based on the recent achievements obtained through the new strategy. Undoubtedly, the new strategy holds sufficient promise towards solving India's food problem; whether it can actually provide the solution will depend upon many factors.[4]

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[3] Cummings and Ray (1969b) observed:

"Approximately 20 percent of net acreage in India is irrigated but less than half of this irrigated area can be classified as having assured water. . ."
As of today, there is no 'new technology' applicable to dry areas which even remotely promises the quantum jump in yields that have been associated with the HYV on irrigated lands. . ."
This is not to argue that genetic breakthrough will not occur if sufficient attention is directed toward any problem. However, the basic fact remains that plant growth requires water at key timings for maximum production. As long as researchers stick to a single crop, the genetic opportunities are limited. A more promising path for research might be to focus on crop and varietal selection for specific moisture conditions and use this information as a base to identify suitable cropping pattern systems for specified areas."

[4] To quote from Cummings and Ray (1969a):

In the long run, however, the exploitation of available production potentials of different food crops will be limited by their effective demands, both for domestic and export purposes. India does not have food grains export commitments at present. The aim is to meet internal needs through internal production. Therefore, production at the all-India level must increase at a rate sufficient to match the corresponding overall needs. Even in such a situation regional problems will exist; growth in production will be uneven among the states and cause regional imbalances. The dimensions of India's future food problem can thus be measured from a knowledge of regional imbalances in demand and supply.

To examine the probable future pattern of regional imbalances, growth in food grains requirement and production in the different states of India is estimated for the years 1986 and 2001 under the assumption of an overall food self-support plan for all items under food grains. Implications of regional imbalances on food management problems are examined by considering two sets of projections under alternative assumptions.

"If research is funded at necessary levels, if production inputs are made available in quantities and at times and places required, and if government price policy continues to provide stable incentive price, then expansion of coverage up to the limits of irrigated- and rain-assured acreages at a fairly rapid rate appears to be promising. If these steps occur, then growth rate in food grains production can more than double the rate obtained before the introduction of the new agricultural strategy."

Projection of Aggregate Food Grains
Demand for Human Consumption

The crucial factor influencing growth in India's food grains demand is evidently her population size. From the beginning of this century the population growth rate has shown a steep upward trend (0.57 percent during 1901-1911 to 2.1 percent during 1970-73 (United Nations, 1974). Unless this trend is arrested, India's population will cross the one billion mark before the close of this century. Feeding these growing millions, even at the current level of consumption, will call for more than doubling the food supply.

Raghavachari (IASP, 1974) has recently worked out six sets of plausible growth paths for the future population of India up to 2001. Of these, the Medium-I projection predicts the country's population will be 724.5 and 924.5 million at the end of 1985-86 and 2000-01, respectively.[5] Even if the per capita food grains consumption is kept at 1956-59 average level

[5] Raghavachari has made the projection at the all-India level. He has preferred the use of his Medium-II projection for discussion on age-sex structure and rural-urban breakup at the all-India level. The present study has chosen the Medium-I projection because it is fairly comparable to the estimates provided by others, including the projection made up to 1986 in the Draft Five-Year Plan document; (Blakeslee, Heady and Framingham, 1973); and (Government of India, 1973). To derive state-wise, rural-urban population estimates from Raghavachari's Medium-I projection, the following procedure was adopted.

(i) Rural-urban breakup at the all-India level was first obtained by assuming the same proportions as estimated by Raghavachari for his Medium-II projection.

(ii) Statewide population growth rates separately for their rural and urban sectors were then estimated by increasing proportionately their corresponding growth rates recorded in the 1971 census such that the derived overall growth rates for the rural and urban sectors were identical with the independent estimates made at the all-India level. The projected population figures are given in Appendix A1.

of 160.6 kilograms per year,[6] feeding the population of above size would require about 116.35 and 148.47 million tons of food grains at the end of 1985-86 and 2000-01, respectively.

Per capita demand, however, will not remain constant at the average 1956-59 level; it will increase mainly due to a rise in income. Plan programs are now geared to achieve a minimum of 5 percent growth rate in agriculture and a 5 to 6 percent growth rate in national income (Government of India, 1973). While this optimism about the country's future economic outlook has no semblance to the past, it is obvious that, in a predominantly agricultural economy like India, the growth in overall economy will greatly depend on the performance of the agricultural sector. It is now generally agreed that the development of the biochemical technology in agriculture has opened wide opportunity by which a 5 percent growth in agriculture, necessary to have a higher growth rate in national income, is not too difficult for India to attain.

Generally, as economic development occurs and leads to a higher standard of living, the demand for subsistence items declines and results in a decline in the magnitude of the corresponding income elasticity coefficient. The income elasticity coefficients for food grains that are

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[6] Most of the demand projections made for India are based on the per capita availability rather than the actual level of consumption. The concept of per capita availability is a hypothetical approximation to the actual level of consumption which can only be obtained from household consumption surveys. A reliable per capita food grains consumption estimate for India was developed by Panse (1961) for the period 1956-59. Sukhatme (1962) further revised Panse's estimate and derived 1956-59 average per capita food grains consumption at the all-India level as 160.6 kilograms per year. The present study uses Sukhatme's estimate as a base for computing food grains demand.

presently obtained for the rural and urban sectors of India are of the order of 0.50 and 0.25 (Ray, 1969). These magnitudes will change if the future economic growth proceeds at a much higher rate. Although the different rounds of the NSS (National Sample Survey) household consumption survey provide little information about any such possible trend in the income elasticity coefficients for food grains, it is reasonable to expect them to decline if the national income grows at a rate nearly double the present rate.

Two alternative situations are considered for projecting the food grains demand at the all-India level: (a) a high income growth path of 5 percent per annum with low rural and urban income elasticities of 0.30 and 0.15,[7] respectively, and (b) a low income growth path of 3 percent per annum, comparable to the recorded performance, with high rural and urban income elasticities of 0.50 and 0.25 as presently obtained. The 1956-59 average is taken as the base and the divergence between the high and low projection is measured from the level attained in 1971.

The results of the exercise (Table 2) suggest a modest increase in India's food grains demand with a not too wide divergence between the high and low income growth generated food grains demanded.[8] For the terminal

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[7] For an elaborate discussion on available estimates of elasticity coefficients, see (Ray, 1969), which also provides a fairly exhaustive bibliography of research papers on estimating elasticity coefficients.

[8] For details see footnotes in Table 2. In making the projection it is assumed that relative prices will remain constant and consumers' tastes and preferences for the various food crops will remain unaltered. For a detailed discussion about the limitations of this approach, see (Ray, 1969).

Table 2. Projected food grains demand for human consumption at all-India level

		Population (million)[a]	National Income at 1960-61 prices (Rs. billion)[b]		Per Capita Income (Rs./year)[c]		Per Capita Demand (Kg/year)[d]		Aggregate Demand (million tons)[e]	
			High Projection	Low Projection	High Projection	Low Projection	High Projection	Low Projection	High Projection	Low Projection
1956-59 (average)	Rural	326.31	-	-	266.2	266.2	163.8	163.8	53.45	53.45
	Urban	77.19	-	-	388.0	388.0	147.0	147.0	11.35	11.35
	All-India	403.50	116.83	116.83	289.5	289.5	160.6	160.6	64.80	64.80
1971	Rural	438.86	-	-	313.0	313.0	178.2	178.2	78.20	78.20
	Urban	109.09	-	-	456.1	456.1	153.4	153.4	16.73	16.73
	All-India	547.95	187.10	187.10	341.4	341.4	173.2	173.2	94.93	94.93
1986	Rural	550.98	-	-	483.8	362.6	204.0	193.4	112.40	106.56
	Urban	173.52	-	-	705.0	528.4	165.0	160.3	28.63	27.82
	All-India	724.50	388.96	291.49	536.9	402.3	194.6	185.5	141.03	134.38
2001	Rural	652.19	-	-	771.0	433.0	257.0	215.1	167.61	140.29
	Urban	272.11	-	-	1123.6	631.0	188.8	170.0	51.37	46.26
	All-India	924.30	808.62	454.13	874.8	491.3	236.9	201.8	218.98	186.55

[a]Population estimates are from Appendix A2.1. The 1956-59 average was estimated from the recorded growth rate during 1951-61.

[b]National income is assumed to grow under High Projection at the rate of 5.0 percent per annum (compound) from the 1971 level. The corresponding rate assumed for the Low Projection is 3.0 percent per annum (compound).

[c]The estimates of per capita income for the rural and urban sectors are obtained from the relations: $y_r = cy_u$ and $y_u = I/(cp_r + p_u)$, where y_r and y_u represent per capita incomes for the rural and urban sectors, p_r and p_u the corresponding populations, I stands for the estimate of aggregate income and c is the ratio of per capita expenditure for the rural and urban sectors as obtained from the tenth round of the NSS (National Sample Survey), the reference period of which was 1955-56.

[d] The estimates of the per capita food grains demand for the rural and urban sectors are determined from the respective values of the variables given in the relation: $d_{it} = \frac{d_{io}}{y_{io}} [y_{io} + e_i (y_{it} - y_{io})]$, where d_{io} and d_{it} are the food grains consumption and demand for the 'i'th sector (rural or urban) in the base period and in year t, e_i is the corresponding income elasticity coefficient and y_{io} and y_{it} are their respective per capita incomes in the base period and in year t. Rural and urban consumption estimates for the 1956-59 average were derived from the all-India average of 160.6 kg/year by using the ratio of per capita food grains expenditures in rural and urban areas as obtained from the tenth round of the National Sample Survey.

[e] Aggregate demand has been calculated by multiplying per capita demand by population.

years 1986 and 2001, food grains demand are estimated around 134-141 million tons and 186-219 million tons, respectively. The projected food grains demand of 94.93 million tons for 1971 is very close to the actual availability of 94.31 million tons for the same year. An almost absent demand-supply gap is thus suggested by the exercise for 1971. This appears likely because food grains prices in India remained remarkably stable during that year.

Regional Requirements of Different Food Grains

The relatively simple income elasticity approach used in projecting the aggregate food grains demand is to be ruled out to determine state demands because of paucity of data. Estimates of state incomes are unsatisfactory. State or regional estimates of income elasticities are either not available or are less dependable than the national figures. In view of these limitations, an indirect method is adopted. State estimates are derived from the projected national food grains demand by using their consumption pattern suitably adjusted for corresponding population growth.

The different rounds of NSS give indices of value of consumption per person of food grains separately by states for the rural and urban areas and thus provides a comparative picture of value of consumption per person for the states relative to that for all India. Table 3 (derived from NSS data) provides state consumption indices of food grains averaged over the years 1956-59 and adjusted for prices and population base adopted

Table 3. State-wide average food grains consumption, 1956-59

	Index of Food Grains Consumption (all-India 1956-59=100)		Per Capita Consumption (in kg./year)		Aggregate Consumption of (in million tons)		
	Rural	Urban	Rural	Urban	Rural	Urban	Total
North							
Jammu & Kashmir	137.7	128.5	225.6	188.9	0.64	0.10	0.74
Punjab & Haryana[a]	95.2	93.1	155.9	136.8	2.31	0.96	3.27
Rajasthan	112.8	111.9	184.8	164.5	2.81	0.50	3.31
Uttar Pradesh	104.3	102.4	171.7	150.5	10.22	1.32	11.54
Total					15.98	2.88	18.86
East							
Assam[b]	126.7	130.0	207.5	191.1	2.47	0.20	2.67
Bihar	113.9	116.4	186.6	171.1	7.32	0.62	7.94
Orissa	87.9	96.5	144.0	141.8	2.19	0.15	2.34
West Bengal	123.2	124.9	201.8	183.6	4.55	1.64	6.19
Total					16.53	2.61	19.14
West							
Gujarat[c]	85.2	86.7	139.6	127.4	2.00	0.64	2.64
Madhya Pradesh	96.2	101.3	157.6	148.9	3.97	0.64	4.61
Maharashtra	82.9	85.7	135.8	126.0	3.36	1.43	4.79
Total					9.33	2.71	12.04
South							
Andhra Pradesh	95.6	102.7	156.6	151.0	4.35	0.88	5.23
Kerala[d]	71.6	82.5	117.8	121.3	1.54	0.29	1.83
Mysore	89.6	91.8	146.8	134.9	2.47	0.66	3.13
Tamilnadu[e]	87.2	95.2	142.8	139.9	3.25	1.32	4.57
Total					11.61	3.15	14.76
All India	100.0	100.0	163.8	147.0	53.45	11.35	64.80

[a] Includes Himachal Pradesh, Delhi and Chandigarh.

[b] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c] Includes Goa, Daman, Diu, Dadra and Nagar Haveli.

[d] Includes Arabian Islands.

[e] Includes Pondicherry.

in this study.[9] Since the NSS data do not provide consumption estimates separately for the union territories, it is assumed that union territories are likely to have the same habits as that of the state with which they are geographically contiguous and climatically homogenous.

Based on these indices, state per capita consumption and aggregate consumption of food grains in the base period 1956-59 average have been estimated (Table 3). The derived estimates suggest that food grains consumption in 1956-59, relative to the national average, was very high in the states of Assam, Jammu and Kashmire and very low in Kerala. Consumption in Bihar, Rajasthan, Uttar Pradesh, and West Bengal also was higher than the national average.

Evidently, food grains demand will grow at a slower rate in the existing high consumption states. An opposite trend is expected in the existing low consumption states, and as far as food grains as a whole is concerned, it would not be unrealistic to expect in the long run the emergence of a uniform consumption pattern for the different states. All these imply that the state-wide food grains consumption pattern estimated for the base period will not remain invariant over time.

State food grains requirements are estimated under the assumption that the additional increase in aggregate food grains demand over the

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[9]These are obtained first by deflating the NSS indices by the corresponding all-India food grains price index for that year and then averaging over the period to obtain consumption index Q_j for the jth state. The indices are further adjusted for the population base adopted here by using a correction factor $(\Sigma Q_j N_j)/\Sigma N_j)$, N_j being the average of 1956-59 population for the jth state. In the absence of a retail food grains price index in India, a wholesale price index is used as the deflator.

base period estimated at the all-India level separately for the rural and urban sector will be distributed over the different state's rural and urban sectors in proportion to their corresponding increase in population. The increments thus estimated are added to the base consumption levels of the respective states to derive state, rural and urban requirements of food grains in 1971, 1986, and 20001 (Appendix A2).

The NSS seventeenth round (draft report)[10] provides some insight into the commodity-wise consumption pattern in the different states rural and urban sectors (Appendix A3). Based on this report, the Indian states can be divided into three categories: (a) Predominantly rice-eating eastern states of Assam, West Bengal and Orissa, the southern states of Andhra Pradesh, Kerala and Tamilnadu, and the northern states of Jammu and Kashmir; (b) Basically wheat-eating northern states of Punjab, Haryana, and Uttar Pradesh; and (c) Gujarat, Maharashtra, Mysore, and Rajasthan where more coarse cereals are consumed. The states of Bihar and Madhya Pradesh appear as intermediate states between category a and category b.

Requirements for different items by commodity under food grains at the state level are derived from their estimated food grains requirements under the assumption that the dietary habits over states will remain the same as obtained in the NSS (National Sample Survey) seventeenth round (Appendices A4 through A6). For cereals and pulses subgroups within food grains, the requirements thus estimated compared favorably with their corresponding availabilities in 1971 (actual availabilities of 84.0 million

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[10] The reference period for NSS seventeenth round was September 1961, to July 1962.

tons of cereals and 10.3 million tons of pulses against their corresponding estimated values of 85.2 and 9.7 million tons. The requirement for pulses has been derived by subtracting the estimated cereals consumption from the estimated food grains consumption demand for humans). However, for the individual items within the cereals group, rice and wheat differed significantly from their 1971 availabilities. Rice was overestimated by 6 million tons, and this was cancelled by an underestimate of the same order in wheat. Two explanations can be put forward for this discrepancy. Consumers might have compensated their unsatisfied rice demand by wheat, the availability of which has significantly increased in recent years because of a steep rise in its production. Again, the magnitude of the income elasticity coefficient for wheat in India is consistently obtained at a much higher level than that for rice, and the discrepancy could also be attributed to a real increase in wheat demand.[11] As economic development takes its stride and breakthroughs are also achieved in rice cultivation, it is likely that demand for coarse cereals will decline and demand for rice and wheat increase. The derived commodity-wise requirements can, therefore, be taken only as lower limits for rice and wheat.

The estimated requirements thus far cover only human needs. To arrive at the total requirements of different items under food grains, allowances also have to be made for seed, feed and wastage. The usual practice is to assume the following percentages of gross production for seed, feed and wastage: rice (7.6 percent), wheat (12.1 percent), cereals

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[11]The estimated income elasticity coefficient for wheat in India is in the range of 0.60 to 0.99; for rice it is only between 0.20 to 0.36 (Ray, 1969).

(12.5 percent) and food grains (12.5 percent).[12] Using these disappearance factors, total domestic requirements at the all-India level are obtained on the assumption that crop-wise gross production equals their respective total domestic requirements (Table 4).

The implied average annual compound growth rate in food grains demand between 1971 and 20001 is 2.26-2.81 percent for rice, 2.50-3.01 percent for wheat, and approximately 2.28-2.83 percent for both all cereals and all food grains. These are comparable to the past production growth rates. Apparently, the results of the exercise give an impression that India could well manage future food problems by marginally improving the present trends in production. This conclusion is, however, deceptive because the various restrictive assumptions under which the projection is made. It is obvious that the derived growth rates can at best be taken as the necessary minimum. In fact, production will have to increase at a higher rate if the family planning program of the government fails to produce its intended impact. Again, export possibilities are completely excluded. Finally, what is most important, a stochastic free growth rate in food grains production is assumed for deriving the total domestic requirements. The task ahead is a challenge but nevertheless can be met if the potentials of the new agricultural strategy are properly exploited.

Regional Food Grains Production Prospects

Suppose now, at the national level, the country is self-sufficient, i.e., the domestic production of individual crops under food grains equals

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[12] These official estimates, which were derived from the Farm Management Survey, have been challenged by several research workers (Ray, 1969).

Table 4. Total requirements of different food grains at all-India level (million tons)

		High Projection		Low Projection		Average Annual Compound Growth Rate (calculated from 1971 level)	
	1971	1986	2001	1986	2001	High Projection	Low Projection
Rice							
For human consumption	44.54	66.82	102.37	62.72	87.17		
Seed, feed and waste	3.66	5.50	8.42	5.16	7.17		
Total	48.20	72.32	110.79	67.88	94.34	2.81	2.26
Wheat							
For human consumption	15.04	23.03	36.63	22.04	31.58		
Seed, feed and waste	2.07	3.17	5.04	3.03	4.35		
Total	17.11	26.20	41.67	25.07	35.93	3.01	2.50
All Cereals							
For human consumption	85.22	126.72	196.77	120.70	167.53		
Seed, feed and waste	12.17	18.10	28.11	17.24	23.93		
Total	97.39	144.82	224.88	137.94	191.46	2.83	2.28
All food grains							
For human consumption	94.93	141.03	218.98	134.38	186.55		
Seed, feed and waste	13.56	20.15	31.28	19.20	26.65		
Total	108.49	161.18	250.26	153.58	213.20	2.82	2.28

their respective effective demands estimated under the high or low projection. Then under the self-sufficiency assumption, the long-run production growth rates of individual crops at the all-India level are predetermined. Given the all-India growth rates in production, what will be the corresponding long-run regional growth rates? Will these follow the past pattern?

The food problem in different states of India is essentially a food grains problem. Towards this end, each state produces food grains; in fact, a major part of the agricultural production in each state of India is made of food grains. Unless there is a dramatic change in food habits (which is very unlikely) this trend will continue. Therefore, it is reasonable to assume that each state will continue to produce food grains. Production in each state is, however, a function of land, labor, capital, macro-ecological conditions, and a host of other factors. In the long run, some of these factors will evidently appear as constraints and limit furhter growth in production. The relative share of the different states in the country's total future food grains production will, therefore, depend on exploitation, to the extent possible, of the various factors of production.

Since the scope for increasing the land base is now almost limited in all the states, any major increases in future production must come through intensive cultivation. The high-yielding varieties provide this opportunity through intensive exploitation of land, water, fertilizer, and other inputs. The technical skills involved in the cultivation of high-yielding varieties are at present unevenly distributed among the cultivators, both between and within the states. With the passage of time, this situation is likely to even out to a large extent. However, with water being an important factor for the new technology, the growth in irrigated acreage among the states will be a limiting and shaping force for long-run regional growth rates.

Recent achievements indicate that although the impact of new technology is perceptible in all Indian states, the adoption of high-yielding varieties and the consequent production increase is generally high in the present high growth-generating states. This is made possible by the existing large irrigation facilities in these states. The approximate distribution of unexploited irrigation potential in the country ranges from 0.58 percent of land in Jammu and Kashmir to 18.48 percent in Uttar Pradesh (Appendix A7). The present high growth-generating states are already utilizing a major proportion of their irrigation potential. On the other hand, states like Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, and Bihar have large water resources as yet untapped. Based on current knowledge and existing technology, the present high growth-generating states are likely to reach a technological plateau much earlier than the present slow growth-generating states.

A rapid development of the economy through an accelerated growth in agriculture will necessitate increasing utilization of the untapped resources of the country. If it is assumed that this will be obtained primarily through greater utilization of the irrigation potential then the estimated regional growth rates in food grains production are likely to undergo dramatic changes in the future. On the other hand, a slow growth of the economy may adversely affect investment in agriculture and result in slowing down the agricultural growth. A food self-support plan under such a situation will demand more efficient use of the existing resources and in the process this may result in preserving the present ranking of the states in production performance.

Following the above arguments, an attempt is made to estimate state food grains production under the high and low income growth generated food grains demand. It is assumed that, at the national level, production of different crops under food grains in 1986 and 2001 will equal their respective effective demand estimated under the high or low projection. Also, to make the demand and production estimates comparable, a normal weather production level based on the average of 1968-71 is used for 1971, the base year for estimating the production increments.[13] The distribution and composition of the normal weather food grains production for consumption in 1971 are obtained by using state average production of different food crops in 1968-71 as weights.

For the projected high demand, state-wise production estimates for food grains as a whole and cereals as a group are made on the assumption that the additional increase in irrigated acreage and in all food grains or all cereals, anticipated at the national level to meet the

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[13]Since there is a time lag in the consumption of crop output, 1970-71 normal weather production level is used for comparison with the demand estimates for 1971. A three-year average of 1968-71 is used instead of 1969-72 because the weather was too bad in 1971-72. Weather was below normal in 1968-69, normal in 1969-70, and above normal in 1970-71. The average of 1968-71 is likely to represent the normal weather production level of 1970-71 more accurately than the average of 1969-72 (Cummings and Ray, 1969a; 1969b).

requirements at the end of 1986 and 2001, over the 1971 level, will be distributed over the states in proportion to the statewide distribution of present unexploited irrigation potential in the country.[14] Regional production estimates to meet the projected low food grains requirements are made by adjusting proportionately to the state growth rates in food grains and cereals production as recorded between 1961 and 1971.

Estimated Cereals Production Pattern

The future acreages under different food crops will be largely determined by their future relative prices and gains in productivity. The new technology has proved beyond doubt a higher yield potential for wheat, and with further breakthroughs in rice production it is likely that these two superior grains will bring increasing acreage planted to cereals.

Such changes are already visible. For instances, some of the eastern and southern states of India now produce wheat contrary to earlier custom. However insignificant such a transfer may be to the country's total wheat production, the question is whether these trends recently noticed are likely to increase over time. In all probability such attempts will have only short half-lives and the influence of macro-ecological factors will limit such attempts.

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[14] Pulses are intercropped with cereals in all states. An increase in cereals production in any state is, therefore, likely to increase its pulses production, too. In other words, growth in the production of food grains as a whole and cereals as a group in the different states will be influenced by the same factors.

The geographical concentration and specialization of production is largely influenced by the macro-ecological factors. Variables other than macro-ecological ones can introduce a dynamic element in the production pattern of a region. However, they are unstable. In contrast, the macro-ecological characteristics of an area are practically stable over a long period of time. In the long run, these characteristics will force the farm firms of an area to choose, from among many production alternatives, one or a combination of some. The past food grains production pattern in the different states was an outgrowth of these macro-ecological conditions. Future changes are likely to be consistent with this pattern; probably, the new technology will intensify the specialization.

To estimate the cereals production pattern for the future years one possibility is to assume that the state future production patterns will remain the same as in 1971. In that event, self-sufficiency will not be attained for all items under food grains. Rice will be in short supply, and more wheat and coarse cereals will be available than necessary. Demand pressure will thus compel the states to produce more rice and less wheat and coarse cereals--subject, of course, to regional macro-ecological limitations.

Obviously, the future cereals production patterns over states under the high and low projection will have some consistency with the present. For the present work it is assumed that the weights of different crops in each state's total cereals production will change proportionately, subject to certain constraints. More precisely, if W^o_{ij}

is the weight of the jth crop in the ith state's total cereals production for 1971 then for the year t it is assumed that

$$W_{ij}^{t} = K_{j}^{t} W_{ij}^{o} \text{ for all i and a given j}$$

subject to the conditions

(i) $\sum_{i} W_{ij}^{t} X_{ie}^{t} = X_{j}^{t}$ for all j

(ii) $\sum_{j} W_{ij} = 100$ for all i, and

(iii) $0 \leq W_{ij}^{t} \leq 100$

where X_{ie}^{t} is the ith state's estimated total cereals production (estimated under high or low assumptions) and X_{j}^{t} is the production of the jth crop in year t anticipated at the all India level (under the high or low projection) for attaining self-sufficiency in it. If W_{ij}^{t} equals 100, then the ith state will produce only the jth crop under cereals--an extreme case of optimum specialization of production under macro-ecological conditions. Subject to the above restrictions some of the W_{ij}^{t}s can be kept fixed at preassigned levels, if there are <u>a priori</u> reasons to do so. The values of W_{ij}^{t}s can be computed by successive iterations.

For the present work, the cereals group in each state is divided into three categories - rice, wheat and coarse cereals (j running from 1 to 3). Determination of optimum weights for rice and wheat will, therefore, automatically determine the optimum weight for coarse cereals (for each state it will be 100 minus optimum weight for rice and wheat). Also, as there is no information available regarding the future cereals production pattern of any state, weights are allowed to take the extreme values ranging from 0 to 100.

The estimated rice and wheat production pattern over states and the corresponding absolute production under the high and low projection for attaining self-sufficiency in these two crops at the all-India level in 1986 and 2001, are given in Appendices A9 and A10. Since the estimated state production of rice, wheat and all cereals is derived on the assumption of overall self-sufficiency, state coarse cereals production (which for each state is the estimated total cereals production minus the total of estimated rice and wheat production) will also obviously add up to make the country self-sufficient in it. The system is thus closed at the national level in that overall domestic production of each item under food grains equals its corresponding domestic requirement.

Some interesting results follow from the two sets of regional production estimates (Table 5). The long-run growth rate in food grains production in Punjab and Haryana, though estimated to hold the top rank among the states under the low projection, is seen to have been practically pushed down to the bottom under the high projection. Andhra Pradesh and Kerala, which are estimated to record low growth rates under the low projection, improve their performance considerably under the high projection to occupy first and second places, respectively. Similar results are also obtained in state growth rates of different crops under cereals. A complete reversal in the ranking of the states in production performance is thus likely to occur if the future food grains

Table 5. Required growth rates for attaining self-sufficiency in food grains[a]

	High Projection[b]				Low Projection[b]			
	Food Grains	Cereals	Rice	Wheat	Food Grains	Cereals	Rice	Wheat
North								
Jammu & Kashmir	2.02(13)	1.93(14)	2.38(12)	1.05(10)	3.04(2)	2.90(2)	3.89(2)	1.30(2)
Punjab & Haryana[c]	1.94(14)	1.95(13)	2.40(11)	1.05(10)	4.06(1)	4.25(1)	5.25(1)	2.62(1)
Rajasthan	2.69(9)	2.94(9)	3.45(7)	2.05(6)	2.21(7)	2.35(7)	3.36(6)	0.77(7)
Uttar Pradesh	3.07(8)	3.25(7)	3.72(6)	2.35(5)	2.32(6)	2.56(4)	3.57(4)	0.95(4)
Total	2.64	2.74	3.35	1.76	3.01	3.23	4.06	1.81
East								
Assam[d]	3.38(5)	3.21(8)	2.91(8)	-	2.11(8)	2.00(8)	1.89(12)	-
Bihar	3.30(6)	3.37(5)	3.84(4)	2.45(3)	1.61(12)	1.66(12)	2.66(8)	0.05(9)
Orissa	2.58(10)	2.57(10)	2.48(10)	-	1.76(11)	1.64(13)	1.79(13)	-
West Bengal	2.30(12)	2.25(12)	2.37(13)	1.36(9)	2.63(4)	2.50(5)	2.72(7)	0.94(5)
Total	2.85	2.85	2.90	2.08	2.06	2.00	2.39	0.41
West								
Gujarat[e]	3.73(3)	3.56(4)	4.06(3)	2.66(2)	2.94(3)	2.82(3)	3.84(3)	1.23(3)
Madhya Pradesh	3.61(4)	3.87(2)	4.34(2)	2.95(1)	1.76(11)	1.73(11)	2.72(7)	0.12(8)
Maharashtra	3.21(7)	3.28(6)	3.75(5)	2.37(4)	1.53(13)	1.40(14)	2.38(10)	-0.23(10)
Total	3.53	3.63	4.17	2.83	1.98	1.92	2.77	0.35
South								
Andhra Pradesh	4.50(1)	4.35(1)	4.84(1)	-	1.37(14)	1.23(15)	2.22(11)	-
Kerala[f]	3.96(2)	3.77(3)	3.75(5)	-	1.93(9)	1.78(10)	1.77(14)	-
Mysore	2.47(11)	2.43(11)	2.90(9)	1.52(8)	2.59(5)	2.45(6)	3.46(5)	0.84(6)
Tamilnadu[g]	0.98(15)	0.90(15)	1.37(14)	-	1.95(10)	1.82(9)	2.51(9)	-
Total	3.06	2.94	3.37	1.67(7)	1.98	1.83	2.52	0.49
All India	2.97	3.00	3.30	1.99	2.41	2.45	2.75	1.49

[a] Average annual compound growth rate estimated from 1968-71 average production level.

[b] Number in parenthesis denotes the rank of the state.

[c] Includes Himachal Pradesh, Delhi and Chandigarh.

[d] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[e] Includes Goa, Daman, Diu, Dadra and Nagar Haveli.

[f] Includes Arabian Islands.

[g] Includes Pondicherry.

productions are obtained more from exploitation of the country's untapped irrigation potentials than from the intensive utilization of the existing resource base.

Regional Imbalances in Food Grains

The estimated regional imbalances in food grains (Tables 6 and 7) derived from the high and low demand-supply projections provide rough outlines of the dimensions of future food management problems of India. As mentioned earlier, domestic supply of food grains was highly favorable in 1971 to meet the corresponding requirement. This was because of a bumper crop in 1970-71. Had the weather been normal, there would have been an overall deficit of approximately 4 million tons of food grains in 1971. The normal weather production base assumed for estimating the food grains production pattern suggests that, but for the good crop of 1970-71, domestic supply of different items under food grains would have significantly fallen short of the corresponding requirements in 1971. The only exception was wheat which was estimated to have recorded a surplus of about 6 million tons under normal weather conditions.

The two sets of demand-supply projections provide a range within which the magnitudes of regional imbalances in food grains are likely to occur in the future. Two extreme situations are obtained from the northern and eastern regions of the country. Both the high and low projections suggest that during the remaining part of this century, the northern region will remain surplus on all items under food grains while the eastern region will record a completely opposite situation. For the

Table 6. Projection of regional imbalances in food grains and cereals[a] [surplus (+) or deficit (-) in million tons]

	1971		1986				2001			
	Average of 1968-71		High Projection		Low Projection		High Projection		Low Projection	
	Food Grains	Cereals	Food Grains	Cereals	Food Grains	Cereals	Food Grains	Cereals	Food Grains	Cereals
North										
Jammu & Kashmir	-.09	-.06	-.27	-.26	+.18	+.14	-.58	-.57	+.29	+.21
Punjab & Harayana[b]	+6.19	+5.69	+6.55	+6.16	+19.08	+18.94	+6.83	+6.53	+26.22	+25.88
Rajasthan	+0.94	+.22	+1.23	+.53	+1.12	+.40	+1.52	+.81	+1.61	+.65
Uttar Pradesh	+0.20	+.15	+3.40	+3.61	+2.65	+3.04	+7.86	+8.27	+4.50	+5.61
Total	+7.24	+6.00	+10.91	+10.04	+23.03	+22.52	+15.63	+15.04	+32.62	+32.35
East										
Assam[c]	-1.73	-1.53	-2.21	-2.04	-2.60	-2.47	-3.97	-3.78	-4.24	-3.96
Bihar	-3.70	-3.24	-3.36	-2.73	-5.98	-5.23	-3.09	-2.34	-7.33	-6.28
Orissa	+.75	+.59	+1.10	+.86	+.39	+.03	+.65	+.34	+.03	-.41
West Bengal	-2.13	-2.03	-3.61	-3.48	-2.18	-2.02	-6.27	-6.12	-2.04	-2.44
Total	-6.81	-6.21	-8.08	-7.39	-10.37	-9.69	-12.68	-11.90	-13.58	-13.09
West										
Gujarat[d]	-.79	-.46	-.78	-.45	-.63	-.33	-1.05	-.66	-1.38	-.91
Madhya Pradesh	+2.20	+1.31	+5.06	+4.03	+.63	-.28	+9.20	+7.87	+.77	-.60
Maharashtra	-2.62	-2.48	-4.17	-3.78	-5.97	-5.68	-7.14	-6.40	-9.11	-8.62
Total	-1.21	-1.63	+.11	-.20	-5.97	-6.29	+1.01	+.81	-9.72	-10.13
South										
Andhra Pradesh	-1.07	-.88	+2.46	+2.27	-3.19	-3.14	+7.71	+6.80	-4.02	-3.95
Kerala[e]	-1.92	-1.80	-2.86	-2.73	-3.26	-3.11	-4.44	-4.32	-4.74	-4.54
Mysore	+.54	+.56	+.35	+.41	+1.27	+1.06	-.21	-.15	+1.82	+1.40
Tamilnadu[f]	-.52	-.19	-2.89	-2.40	-1.51	-1.35	-7.02	-6.28	-2.38	-2.04
Total	-2.97	-2.31	-2.94	-2.45	-6.69	-6.54	-3.96	-3.95	-9.32	-9.13
All-India	-3.75	-4.15	0	0	0	0	0	0	0	0

[a] State-wide production estimates are first adjusted for disappearance due to seed, feed, and waste. Imbalances are obtained by subtracting the state wide demands from their corresponding adjusted production estimates.

[b] Includes Himachal Pradesh, Delhi and Chandigarh.

[c] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[d] Includes Goa, Daman, Diu, Dadra and Nagar Haveli.

[e] Includes Arabian Islands.

[f] Includes Pondicherry.

Table 7. Projection of regional imbalances in rice and wheat[a] [surplus (+) or deficit (-) in million tons]

	1971		1986				2001			
	Average of 1968-71		High Projection		Low Projection		High Projection		Low Projection	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
North										
Jammu & Kashmir	-.19	+.02	-.29	-.05	+.04	-.03	-.54	-.09	+.06	-.03
Punjab & Harayana[b]	+.73	+3.83	+1.12	+1.74	+3.35	+5.75	+1.31	+1.34	+4.63	+8.09
Rajasthan	+.03	+.47	+.08	+.11	+.10	-.23	+.11	+.17	+.15	-.35
Uttar Pradesh	-.32	+1.85	+1.34	+1.38	+2.08	-.16	+2.74	+3.36	+3.35	+.33
Total	+.25	+6.17	+2.25	+3.18	+5.57	+5.33	+3.62	+4.78	+8.19	+8.04
East										
Assam[c]	-1.35	-.10	-2.03	-.14	-2.25	-.14	-3.76	-.30	-3.59	-.25
Bihar	-2.28	-.44	-.91	-.83	-2.05	-1.35	-.25	-.97	-2.09	-1.74
Orissa	+.73	-.02	+.99	-.04	+.44	-.04	+.49	-.11	+.23	-.10
West Bengal	-1.94	+.17	-3.41	-.04	-1.36	-.09	-5.36	-.13	-1.52	-.12
Total	-4.84	-.39	-5.36	-1.05	-5.22	-1.62	-8.88	-1.51	-6.97	-2.21
West										
Gujarat[d]	-.10	-.15	+.02	-.58	+.20	-.70	0	-.98	+.16	-1.18
Madhya Pradesh	+.73	+.37	+3.05	0	+1.55	-1.31	+5.51	+.37	+2.15	-1.98
Maharashtra	-.43	-.56	-.32	-1.17	-.83	-1.32	-.74	-2.03	-1.40	-2.09
Total	+.20	-.34	+2.75	-1.75	+.92	-3.33	+4.77	-2.64	+.91	-5.25
South										
Andhra Pradesh	-.30	-.07	+3.45	-.10	-.35	-.10	+7.67	-.15	-.29	-.15
Kerala[e]	-1.72	-.02	-2.60	-.04	-3.00	-.04	-4.12	-.07	-4.38	-.06
Mysore	+.38	-.04	+.80	-.14	+1.59	-.13	+.78	-.24	+2.14	-.22
Tamilnadu[f]	+.10	-.07	-1.29	-.10	+.49	-.11	-3.84	-.17	+.40	-.15
Total	-1.54	-.20	+.36	-.38	-1.27	-.38	+.49	-.63	-2.13	-.58
All-India	-5.93	+5.24	0	0	0	0	0	0	0	0

[a]State-wide production estimates are first adjusted for disappearance due to seed, feed and waste. Imbalances are obtained by subtracting the state wide demands from their corresponding adjusted production estimates.

[b]Includes Himachal Pradesh, Delhi and Chandigarh.

[c]Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[d]Includes Goa, Daman, Diu, Dadra and Nagar Haveli.

[e]Includes Arabian Islands.

[f]Includes Pondicherry.

western region, the high projection estimates a surplus situation on all items except wheat while the low projection indicates surpluses only in rice and pulses. Similarly, the southern region will be deficit on all items except rice under high projection but deficit on all items under low projection. Within each region again, there are imbalances; some states are surplus and some are deficit on certain items under food grains. Both the projections indicate that food grains production in some states might not even be sufficient to meet their corresponding rural requirements. Only the northern region is estimated to record wheat surplus. For rice, the deficit is estimated to occur only in the eastern region under high projection and both in the eastern and southern region under low projection.

The widely varying magnitudes of regional imbalances estimated under the high and low projections have different implications on the government's food management operations. Regional disparities in demand and supply are relatively less pronounced in high than in low projection. Accordingly, the high projection path might not demand serious governmental involvement in future food management operations as the quantities to purchase and to transfer from one area to another are likely to be relatively small. In fact, under the high projection, government purchases and transfers of grains can be significantly reduced through a judicious regrouping of the surplus and deficit states in different food zones. However, serious problems will arise if the demand-supply gap follows the low projection path. Regional disparities will then become more severe in intensity than the present. Since the transfers in this situation are likely to involve huge quantities, the government may not encourage free trade in food grains; the fear of traders' speculation may tempt the government to apply various restrictive measures on free market operations.

The instabilities in production are also likely to differ under the two projections. Thus, if the production grows along the high projection path through an expansion of irrigation facilities, it may also record weather-induced fluctuations of lesser intensity because of more land under irrigation. In essence, this may result in a high production path with a lower variability around it. An opposite pattern is likely to emerge if the production grows along the low projection path. A bad weather year is, therefore, likely to accentuate the regional imbalances estimated under the low than the high projection.

Evidently, for a steady and equitable distribution, the government must ensure, directly or indirectly, adequate transfers of food grains, not only from rural to urban areas or from surplus to deficit states but also from one year to the next in order to make provisions for future production irregularities. Because the magnitudes of regional imbalances are likely to be large, transfer of appropriate quantities at reasonable prices may not be obtained through the private trade alone. Private trade may indulge in hoarding and speculation and fix the mean price at a level sufficiently high to call for the government's direct involvement in food management operations. The extent of such involvement, however, will depend not only on the magnitude of regional imbalances but also on the objectives of the government's food management operations. Thus, the formulation of a stabilization stock program for food management and the identification and estimation of the different components of it can only be in this context of a particular frame of reference, stated in terms of the policy maker's desirability against the backdrop of reality.

IV. WEATHER AND RESERVE FOOD GRAIN STOCKS IN INDIA

The wide fluctuations in food grains production in India generally are attributed to the weather. Recurring droughts or floods have brought uncertainty in production levels and made sustained growth more difficult.

Planning to meet the contingency of these inevitable year-to-year production fluctations is possible in terms of probabilities determined through an analysis of the weather-induced fluctuations in production in different parts of the country. This chapter is an historical analysis of weather-induced fluctuations in India's food grains production. Rainfall seems to be the most important factor in the sharp production fluctuation. Therefore, suitable rainfall indices are computed to make an analysis of the rainfall distribution pattern and its effect on crop output. Finally, variations in production are analyzed with the help of rainfall indices to determine the size of reserve stocks for meeting specific contingencies.

Causes of Production Fluctuations in India

The production of a particular crop in any region is the result of the acreage and its yield per acre. Yield and acreage can be expressed as a function of a number of variables such as fertilizers, pesticides, irrigation, prices, etc., which can be changed through policy instruments and an uncontrolled variable, "W," comprising the various climatic factors like rainfall, temperature, run of dry days, humidity, day length, etc. Any variation in yield or acreage can thus be conceptually partitioned into two components, one arising out of the controlled variables and the other out of the uncontrolled variable "W". According to natural laws, "W" varies and thus causes unexpected variations in yield and acreage and, hence, in production. The various climatic factors enter into the production function of a region as exogenous variables which are determined or fixed by nature. The productivity coefficients of the various endogenous variables in the system differ over space and time because the magnitudes of the exogenous or nature-determined variables vary (Heady, 1965).

Variations in agricultural production can thus be man-made or nature-made. Even if the climatic factors follow some repetitive pattern, the production fluctuations would not be proportional unless the relative magnitudes of the effects of these factors on production remain constant over time. The physical frame of reference in agriculture is, however, not invariant with respect to time; men can influence it through technological advances. The variables that are currently exogenous can be made endogenous to the system through human skill and knowledge at a latter period. Conceptually and practically it is not possible to eliminate the unexpected variation in production due to natural factors. Although on an experimental plot, for example, water, temperture, day length, humidity, wind velocity, etc., can be kept at desired levels with artificial techniques. This idealized proposition is, however, difficult to create when we consider the production function of a region or, for that matter, even of a plot on the cultivator's field. Physical factors appear as constraints on the production surface; their basic differences from region to region lead to differences in land use and cropping patterns.

Soil is the staging area for plant growth and at any location its quality is itself an expression of the climate. The biosphere over the soil depends on the climate, and the basic soil productivity of an area is an expression of the interaction between the biosphere and the climate over years.[1] This basic soil productivity at any location is not subjected to yearly changes, but undergoes a very slow drift over a longer period. For all practical purposes, it is static and cannot be changed. Similarly, when we speak of a region or an area, the natural supply of light, temperature, water in the form of rain, etc. cannot be changed. Their presence or occurrence become inevitable events to the farmers. However, men can influence nature through technological advances. The technology of agriculture in any country, at any period is an expression of the desire to influence the various natural factors which affect production.

Given the basic soil productivity and assuming no change in the technology of agriculture in an area, crop output fluctuates because the relative magnitudes and the occurrence of the various climatic factors at any reference point in time vary from year to year. These variations

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[1]The soil property at any location is expressed by Jenny (1941) as:

$$S = f(cl, b, r, p, t, \ldots)$$

where cl = climate
b = biosphere (vegetation, organism, man)
r = relief (topography)
p = parent material
t = time (age).

in occurrence and relative magnitudes of the various climatic factors neither follow a unified pattern nor do all of them appear as constraints on Indian agriculture. Some fluctuate more than others and make their impact felt on production.

Geographically, India falls within latitudes that encompass all the deserts in the northern hemisphere; strategic locations of hills and mountains save her from complete aridity.[2] The escape is, however, not total. As a result, agricultural pattern differs significantly from region to region.

Studies in many countries to examine the effects of various climatic factors on crop output have singled out rainfall and temperature as the most important influencing factors; other factors which affect the crops also being largely rainfall or temperature dependent.[3] In India, however, temperature does not appear to be responsible for fluctuations in crop output.[4] Also, some factors like snowfall, intensity of light, etc., which generally affect crop output in Western countries, pose small constraints on Indian agriculture.

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[2]Sen (1969) observed: "India, too, would have been a desert but for the location and alignment of its mountains and hills; they have not only saved her (from being a desert by helping precipitation) but also have given rise to a number of rivers whose water irrigates large areas."

[3]There are exceptions to this general statement. For example, the run of dry days, which greatly affects the crops, is independent of temperature and quantum of monthly precipitation. See (Oury, 1965; 1967), (Organization for Economic Co-operation and Development, 1966) and (Thompson, 1962; 1969) which provide fairly exhaustive references on this topic.

[4]An analysis of data (based on analysis of variance) pertaining to about 50 meterological stations of India, published in World Weather Records (U.S. Government, 1967), indicated that monthly variations in temperature over the years (data series ranging from 30 to 90 years) were not significant (some hilly areas were an exception).

On the other hand, variation in rainfall from one year to the next at any location in India and at any point of time within a year is generally more than 100 percent.[5] The uneven distribution of rainfall over the country is due to its wind currents as well as the elevation and topography of the land. The wind currents which bring the monsoon in India, are very erratic and cause great variations in timing and amount of rainfall, and consequently production. Irrigation and flood control can help, but so far their contributions to reducing the fluctuations in rice output have been nominal.[6] More than 50 percent of the present irrigated acreage in the country depends on rainfall. Even the assured rainfall regions in India, covering about one-third of the net sown area, experience drought once in every five years (Cummings and Ray, 1969b).

The economic geography of Indian agriculture suggests that the rainfall distribution pattern is primarily responsible for differences in land use, cropping pattern, settlement, and density of population in different parts of the country. When viewed in the light of the country's limited irrigation potential, the influence of rainfall on crop output will sustain and, perhaps, will be more pronounced as production increases at a faster rate. The uncertainties in rainfall will cause the same old concern; instability will continue to plague Indian agriculture.

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[5] This variation is generally high at the beginning of the southwest monsoon which arrives at different dates spreading from May to July in different parts of the country (observation based on data described in the next section).

[6] Some major irrigation projects and dams constructed after independence have greatly reduced the damages due to floods. Also, unlike droughts, damage to crops due to floods is generally of localized nature and its effect is relatively small on aggregate production.

Rainfall Indices

An attempt to study weather-induced production fluctuations becomes more simple if it is assumed that, for any region in India and at any time reference point, (a) the year-to-year variations in the various climatic variables are, with the exception of rainfall, very small and, (b) the effects of the interactions of rainfall with various other climatic factors on crop output are negligible. The fluctuations in production because of weather can be attributed mainly to rainfall. Hence, the main need is to study the distribution of rainfall and its effect on crop output. This is probably an oversimplification of the actual mechanism through which the various climatic factors influence crop output. However, the need to consider other climatic variables will arise if rainfall is unable to explain the greater part of the fluctuations in production. As will be indicated later, rainfall alone explains most of the variations in output due to uncontrolled factors.

Another important reason for restricting the analysis to rainfall is the paucity of fairly long time-series data on various climatic variables. Fortunately, fairly long time-series data on rainfall are available for a large number of meteorological stations in India. Meteorologists have divided India into 33 rainfall subdivisions according to the rainfall distribution pattern.[7] Data relating to approximately 232 stations are presently used in the published official weekly reports. Of these, 133 stations, with 2 to 6 from each of the 33 subdivisions,

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[7] The total number of rainfall subdivisions has been increased recently from 33 to 36.

have rainfall records dating back to 1875.[8] The time-series data of these 133 stations are condensed to 33 rainfall subdivisions series (monthly, from 1975 to 1966) by taking a simple average of the stations falling within each of the rainfall subdivisions (see Appendix B).

The effect of rainfall on crop output at any location is very difficult to measure because it is not only the volume of rainfall but also its distribution at different stages of plant growth that influences the total output. The adequacy and timeliness of the rainfall at the sowing period affects the amount of sown acreage. Similarly, the volume and distribution of rain at the time of sowing, flowering, maturing, and harvesting, affect crop yields. Consideration of these issues would necessitate introduction of a large number of explanatory variables into the crop rainfall relationship. The problem is that the short production data series of less than 20 years does not provide scope for a rigorous analysis. Use of a large number of explanatory variables in the structural equation will reduce the precious degrees of freedom for estimating the parameters with an adequate level of confidence. Again, the crop calendar is not the same throughout the country. For example, rice is sown and harvested at different times in the various states and,

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[8]Rainfall data of these 133 stations are not available in published form. They are obtained through the courtesy of Dr. S.R. Sen and Mr. J.S. Sarma from the Indian Meteorological Department. For details, see Appendix B.

therefore, is influenced by the adequacy and timeliness of rainfall during the crop's growth. Taking account of all of these differences obviously poses serious problems in statistical estimation, unless the various factors are reduced to a manageable limit. Consequently, aggregation of the rainfall data from different parts of the country into some suitable rainfall indices at the state and national level become essential.[9]

We construct two rainfall index series at the meteorological subdivisional, state, and national levels -- one for cereals as a whole and the other for rice, a principal crop in India production of which is greatly influenced by the monsoons (see Appendices C1 to C3). The indices are constructed by assigning suitable weights to the volume of rainfall in different periods within a year for each of the meteorological subdivisions. The average of 1959-62 production is taken as the base for computing the indices. All the index series are computed in a manner such that they have the same mean (rainfall index 100) but different dispersions (for details, see Appendix C).

The historical record of famines in India provides scope for testing the reliability of indices thus computed. In the early years there was very limited movement of food grains among the different parts of the country, and regional scarcities were attributed to crop failures because of floods or droughts. If the indices are fairly good, these should

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[9]Many ambitious formulae have been developed for constructing composite weather indices. Of particular interest is the Program Windex developed by Oury (1967) though its use in an aggregate analysis is rather difficult. See (Organization for Economic Co-operation and Development, 1966) for a review of various formulae for computing composite weather indices.

then record very abnormal values (too high or too low from the average) on famine-affected years of different regions. That this was so is clearly evident from a comparison of the cereals rainfall indices with the historical record on famines in different parts of the country since 1875 (Table 8).

Table 8. Famines in India

Year	Parts of the Country Affected[a]
1876-77	Madras (63.9), Maharashtra (67.0), Mysore (70.0), Andhra Pradesh (68.2)
1877-78	Madhya Pradesh (67.6), Gujarat (49.2), Rajasthan (35.2), All India (75.0)
1878-79	Assam (128.6), Bihar (129.4), Uttar Pradesh (129.1), Gujarat (185.3), Maharashtra (137.7), Andhra Pradesh (153.6)
1884-85	Bengal (80.9)
1886-87	Madhya Pradesh (78.3)
1887-88	Orissa (78.9)
1888-89	Andhra Pradesh (66.9)
1890-91	Kerala (79.2)
1891-92	Bengal (79.4), Bihar (87.7), Punjab (72.7)
1899-1900	All India (73.0)
1905-06	Maharashtra (65.7)
1907-08	Uttar Pradesh (52.5), Punjab (61.3), Madhya Pradesh (75.0)
1918-19	All India (77.4)
1965-66	All India (84.5)

[a]Number in parentheses denotes the cereals rainfall index.

Source: (Sen, 1967; Bhatia, 1967).

Moreover, if the indices are reasonably good, the distribution pattern from 1875 should have some semblance with the corresponding production pattern. The yearly fluctuations in the national cereals rainfall index was less severe during 1924-25 to 1950-51 than during the period 1900-01 to 1923-24 (Table 9). This is consistent with Sen's findings, and suggests that the relatively stable and unstable periods in past food grains production were largely because of rainfall (Sen, 1967).

Table 9. Decade-wise mean deviation in all India cereals rainfall index

Decade	Above Normal		Below Normal	
	Frequency	Mean Deviation	Frequency	Mean Deviation
1881-1891	8	4.7	2	4.9
1891-1900	5	12.9	5	10.3
1901-1910	5	5.4	5	15.1
1911-1920	4	11.4	6	13.0
1921-1930	5	3.0	5	6.0
1931-1940	5	6.3	5	5.8
1941-1950	7	5.7	3	4.5
1951-1960	7	9.5	3	12.0

Effect on Rainfall on Aggregate Production

A comparison of the historical production pattern with the computed rainfall indices is, however, not possible. Evidently, the weights used in computing the indices would be different as one moves into the historical past. The indices are, therefore, unlikely to provide a one-to-one correspondence with the historical production record even if all details were available. The base period used in computing the rainfall indices reflects the current regional production pattern of different food crops and thus makes the indices more suitable for analyzing the recent production data series.

For analysis of the rainfall effect on crop output, we shall consider the period 1950-51 through 1964-65, the last year before the introduction of the New Strategy. During this period, fertilizer consumption was quite low;[10] irrigated acreage increased but the percentage of

[10]Consumption of chemical fertilizer in India increased from 65,700 tons NPK in 1952-53 to 712,000 tons NPK in 1964-65. Fertilizer use during this period was, however, mostly confined to commercial crops.

the total remained more or less constant; high yielding varieties, with the exception of jowar, bajra, and maize were not introduced and production increased mainly because of the addition of new land and improved practices being applied with the existing technology. Identification and measurement of the various factors which contributed towards increased production during this period are practically impossible as there are hardly any representative data available for carrying out a rigorous statistical analysis. The cumulative effect of all these factors has, however, caused a trend-like movement in production. Both linear and exponential trend lines fitted to the area, production, and yield data for cereals and rice from 1949-50 through 1964-65 recorded significant time trend at the all India level (Government of India, 1966a). Fluctuations around these trend lines occurred owing to a host of factors, one of which was obviously rainfall.[11] Therefore, it appears logical to consider the actual observation as a function of time (a proxy for inputs) and rainfall.

Three relationships were considered to analyze at the national level: the influence of rainfall (W_t) on area (A_t), production (X_t), and yield (Y_t) for cereals as a whole and also for rice separately.

$$A_t \text{ or } X_t \text{ or } Y_t = a_o + a_1 + a_2 W_t \quad (1)$$

$$A_t \text{ or } X_t \text{ or } Y_t = a_o + a_1 T + a_2 W_t + a_3 W_t^2 \quad (2)$$

$$\log A_t \text{ or } \log X_t \text{ or } \log Y_t = a_o + a_1 T + a_2 \log W_t \quad (3)$$

where T is a linear integral valued time variable with values 1, 2, 3... and W_t is the rainfall index for cereals or for rice.

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[11] Throughout the discussion here, trend line is defined by keeping the rainfall index constant at 100.

Equation (1) is linear in time and rainfall; it ignores the adverse effect of excessive rainfall such as a flood. The quadratic term W_t^2 in Equation (2) is included to take into account this effect; it introduces a single curvature in the regression surface. Area, production, or yield changes under this relationship occur from one index point to another with an optimum at $W_t = -(a_2/2a_3)$. Consistent results would require $a_2 > 0$ and $a_3 < 0$ (if too much or too little rain has a detrimental effect, the surface should record a single maxima on the positive quadrant). Variations due to rainfall is superposed over an exponential growth curve. Since the marginal increase in production is likely to decrease with increase in W_t we should expect a_2 to lie between 0 and 1.

Details of the regression analysis, carried out at the all India level with the data from 1950-51 through 1964-65 (Appendix C8) provided some interesting results (see Appendices C9 and C10). Either Equation (1) or Equation (3) can explain more than 90 percent of the variations in cereals area, production, and yield and indicates strong positive effects of rainfall. Similar results also are obtained for rice; however, both equations suggest that rice acreage is not significantly influenced by rainfall. Equation (2) hardly improves the value of R^2 from that obtained by using either Equation (1) or Equation (3). However, in all cases, it provides W_t and W_t^2 coefficients with consistent signs.

Though insignificance of W_t and W_t^2 coefficients does not speak positively for Equation (2), the consistent signs of the coefficients suggest that the indices are probably not sensitive enough to measure the flood effect on area, production, and yield. However, even with very sensitive indices, it is difficult to measure the effect of floods in an all-India analysis. Although floods are frequent in all areas of the country, their effect on the aggregate level is relatively small. Equation (2) will, therefore, be more appropriate for use in regional analysis.[12]

The significant coefficients and high value of R^2 are not sufficient to attach confidence on the impressive results provided by either Equation (1) or Equation (3). In fact, they are deceptive. The high value of R^2 is obvious because of the highly significant trend variable which practically explains all the variations. The value of D-statistic is low enough to suspect positive serial correlation. This is particularly so for acreage and suggests that a linear time variable is not adequate to explain the trend in acreage; its use can be reasonably justified only for production and yield analysis. Even if we ignore these, there are some conceptual problems that speak against the use of Equation (1) and against the mode of analysis. Equation (1) has apparently provided good fit to area, production, and yield data. However, by definition, production equals yield multiplied by acreage and only Equation (3)

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[12] This is substantiated from an analysis of state cereal yields over states. Equation (2) fitted to the cereals yield index from 1952-53 through 1964-65, provided for all the states W_t and W_t^2 coefficients with consistent signs. The states which provided significant results are given in the Table below [cereals yield data from Government of India (1966a) and rainfall index from Appendix C5.]

satisfies this definitional identity, since

$$\log X = \log (AY) = \log A + \log Y.$$

Of the three relationships considered, the choice is therefore limited only to the form postulated in Equation 3.[13]

Again, with favorable rain, marginal lands are generally brought under cultivation. Evidently, the average yield will be adversely affected unless the marginal lands are of the same quality. The actual effect of rainfall thus gets obscured in an average yield analysis because of the interaction between acreage and productivity. In this context, yield-rainfall analysis is debatable.

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		Estimated Coefficient of [a]			
	Constant	T	W	W^2	R^2
Assam	-20.84	-0.03	2.20*	-0.0100*	0.69
		(0.02)	(0.63)	(0.0030)	
Orissa	-69.16	1.45*	2.78*	-0.0116*	0.64
		(0.59)	(1.22)	(0.0056)	
Rajasthan	-100.11	0.24	3.80*	-0.0166*	0.57
		(0.56)	(1.13)	(0.0050)	
Madhya Pradesh	-102.43	1.38*	3.28*	-0.0140*	0.68
		(0.42)	(1.12)	(0.0051)	
Gujarat	-103.52	4.19*	3.46*	-0.0139*	0.72
		(1.20)	(1.11)	(0.0046)	
Maharashtra	-104.32	1.12*	4.07*	-0.0204*	0.74
		(0.58)	(1.63)	(0.0083)	
Mysore	-92.93	2.72*	3.43*	-0.0153*	0.92
		(0.32)	(1.00)	(0.0046)	
Kerala	+35.06	2.84*	0.81*	-0.0030*	0.96
		(0.24)	(0.32)	(0.0014)	

[a]Figure in parentheses denotes standard error. * = significant at the five percent level.

If Equation (3) is accepted for yield, acreage, and production analysis, then for consistent results, the coefficient of W_t estimated from production data should not be significantly different from the total of the corresponding coefficients estimated from yield and acreage analysis. In the derived results (Appendices C9 and C10). The total of the W_t coefficients estimated from cereals acreage and yield data is 0.36 (=0.12 + 0.24) and that for production is 0.36; similarly, for rice the corresponding values are 0.56(=0.06 + 0.50) and 0.56. Since the values are identical, the need for a statistical test of significance does not arise here.

Our primary concern is to explain production fluctuation around its trend line. These fluctuations are due to the joint effect of yield and acreage fluctuations and these, we postulate, arise mainly from the year-to-year variations in rainfall. If the indices are reasonably good, it should then be possible to explain a greater part of the residual variations in production around its trend line. Since an exponential growth curve explained reasonably well the trend in production during the period studied, it follows that the year-to-year changes in production would have remained constant if there were no variations in rainfall from one year to the next. However, since the latter varied, the relative changes in production also recorded fluctuations. Taking the first differences, therefore, it follows from Equation (3) that

$$\log X_{r,t} = a_1 + a_2 \log W_{r,t} \qquad (4)$$

where $X_{r,t} = 100\ (X_t/X_{t-1})$ and $W_{r,t} = 100(W_t/W_{t-1})$

The above equation expresses relative change in the current year's production solely as a function of relative change in the current year's rainfall and explains the fluctuations in production around the assumed form of constant production growth rate (which is the antilog of $a_1 + 2a_2$) curve. However, studies conducted at micro-levels suggest that farmers in India make rational acreage allocation with the objective of maximizing expected profits.[14] These studies usually suggest a Nerlovian type adjustment lag model, a modified version of which in logarithimic form can be stated as follows (Maji, Jha, and Venkataramanan, 1971):

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[14]For reference, see footnote 8 in Chapter II.

$$\log A_t^* = b_o + b_1 \log P_{t-1} + b_2 \log W_t$$

$$\log A_t - \log A_{t-1} = B (\log A_t^* - \log A_{t-1})$$

and the two together in reduced form provide

$$\log A_t = a_o + a_1 \log P_{t-1} + a_2 \log A_{t-1} + a_3 \log W_t.$$

where P_{t-1} is the previous years relative price of the crop, A_t^* is the planned acreage, and other variables are as defined.

Additional variables like lagged yield, total irrigated area, etc., and such other variables hypothesizing risk aversion rationality on the part of farmers (Behrman, 1968; Maji, Jha and Venkataramanan, 1971) can be easily considered in the structural equation. However, not all the variables have always provided significant results in micro studies and as observed by Raj Krishna even farmers' response to economic incentives cannot be asserted for everywhere in the country (Krishna, 1967).

Even if the Indian farmers' response to economic incentives is accepted as applicable throughout the country, there are serious limitations to estimate it for an analysis at the national level. First, no data are available representing national farm prices of a commodity. Second, even if these prices were available, determination of relative prices for use in a national analysis is, itself, a subject of considerable research. The two items those being considered here, cereals group and rice, are of year-round activity in India and as such all other crops practically compete against them. Determination of national relative prices of these two items will require careful weighting of the regional relative prices. Any such attempt meets with frustration because of lack of information and paucity of data.

Some micro-level studies suggest that farmers are more influenced by absolute than relative prices (Maji, Jha and Venkataramanan, 1971). The implication could be that in traditional and subsistence agriculture, the farmer's ability to switch over to alternative crops according to economic signals is limited; marginal adjustments occur only to the extent opportunity permits.

At the national level, such an opportunity can be reasonably explained by considering the previous year's production or yield or rainfall as an influencing factor for acreage allocation. In a traditional and subsistence agriculture, farmers more or less follow a rigid cropping pattern. Acreage allocations are made with the expectation of certain yield levels. The actual acreage, however, deviates from the expected because of the over-riding influence of monsoons. If the realized yield exceeds expected level, the resulting comfortable position provides opportunity to the farmers to grow next year some other crops in addition to their traditional crops. These individual actions of the farmers (influenced more by climatic than economic factors) are likely to make a significant cumulative impact at the national level. The reverse is likely to occur if the realized yield falls short of expectation. If this hypothesis is correct, then the inclusion of the previous year's rainfall or yield or production as an independent variable in the estimating equation should more adequately explain past production fluctuations around the trend.

We have endeavored to explain past production fluctuations by considering various combinations of the variables W_t, W_{t-1}, Y_{t-1}, and P_{t-1} in the estimating equation, the details of which are given in Appendix C11. The conclusions are:

(1) In general, the inclusion of lagged variables improve the value of R^2.

(2) The coefficient of W_t is remarkably stable.

(3) The previous year's above normal rainfall or yield or production has a significant negative effect on the current year's production.

(4) The previous year's price has a positive but insignificant effect on the current year's production.

The equations considered appropriate for estimating the reserve stocks are:

Cereals: $$\log X_{r,t} = 1.6660 + \underset{(0.0894)}{0.3545^*} \log W_{r,t} - \underset{(0.0808)}{0.1799^*} \log W_{r,t-1} \quad (4.1)$$

$$(R^2 = 0.72,\ \text{D-Statistic} = 2.28)$$

Rice: $$\log X_{r,t} = 1.6468 + \underset{(0.1316)}{0.5004^*} \log W_{r,t} - \underset{(0.1308)}{0.3153^*} \log W_{r,t-1} \quad (4.2)$$

$$(R^2 = 0.74,\ \text{D-Statistic} = 2.70)$$

(Figure in parentheses denotes standard error. Significance at 5 percent level is denoted by *).

The above equations can be read as follows: If the production trend line is defined as one corresponding to the normal rainfall index 100, then a one point rise above normal in the current year's rainfall index will cause cereals production to record a positive deviation of 0.35 percent of the corresponding trends value (0.50 percent for rice). If the previous year's rainfall was one point above normal, it would depress the current year's cereals production by 0.18 percent of the corresponding trend value and similarly, 0.32 percent reduction will take place in rice production.

Thus, 70 percent of the variations in cereals and rice production around their respective trend lines can be accounted for by past and current rainfall. Weather-corrected growth rates, computed from these estimated equations, suggest that if rainfall were uniformly the same during this period, cereals and rice production could have increased at higher rates than was actually recorded.[15] The above equations do not include any policy variable and attribute production fluctuation entirely to rainfall. This weakness is acknowledged. Because the primary cause of production fluctuation is uncertain weather, short term policy measures can only help to influence the level of production but cannot stabilize it.

Distribution of Rainfall Indices

The frequency distribution of state cereals and rice rainfall index revealed some interesting results (see Appendices C6 and C7). The cereals and rice rainfall index for each state has a unimodal distribution; however, the distribution has varied widely from state to

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[15] Weather-adjusted, annual compound growth rates for cereals and rice were obtained as 3.51 and 3.99 percent. The corresponding weather unadjusted rates were 3.16 and 3.37 percent (Government of India, 1966a).

state. The variability in the cereals and rice rainfall index is relatively higher in the northern than the eastern states. Also, the present food surplus states have higher variability in rainfall than the deficit states.

Large sample tests, carried out on the observed frequency distribution of the rainfall indices, suggest that the assumption of normality in rainfall distribution is statistically valid for all the states' rainfall index series.[16] The question that is uppermost in one's mind, however, is whether the distribution of these rainfall indices follows a stochastic process. Specifically, the question is whether the realization of different values of rainfall indices is independent of time or follows a definite pattern. As already pointed out, the national cereals rainfall index series followed a pattern closely resembling the historical production record. The amount of oscillation in the cereals rainfall index, itself, oscillated and recorded alternatively and relatively higher and lower oscillations of roughly 24 years span. Is this phenomenon (observed in the last 90 years' rainfall data) because of a chance relationship or is there any deeper significance in the relationship?

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[16] For testing normality, the computed statistics

$$|w_1| = |\gamma_1/(6/n)^{1/2}|$$

$$|w_2| = |\gamma_2/(24/n)^{1/2}|$$

are compared with a normal distribution with zero mean and unit standard deviation, where

γ_1 = coefficient of skewness $= \mu_3/(\mu_2)^{3/2}$,
γ_2 = coefficient of kurtosis $= (\mu_4/\mu_2^2) - 3$,

μ_2, μ_3, μ_4 are second, third, and fourth central moments and 'n' is the total frequency (Kendall and Stuart, 1958).

The available statistical tools are hardly adequate (Kendall and Stuart, 1966) to solve the complexities of the problems involved in identifying the hidden periodicities in the rainfall distribution pattern. A rigorous study of the joint distribution of divisional rainfall indices would involve mathematical complexities to the point of practical impossibility. Spectral and cross-spectral analyses provide some promise; unfortunately, the series we have is too short for the application of these sophisticated techniques (Granger, 1964).

We shall, therefore, consider a less ambitious approach and examine whether the distribution of rainfall indices could be treated as random. Since all our calculations will be based on the results derived from an all-India analysis, we shall examine here for randomness only in the all-India cereals and rice rainfall index series. It might be noted that the conclusions which we shall arrive at are only approximates; for the all-India series is an agglomeration of a complex phenomenon generating a substantial number of different rainfall distribution patterns in different parts of the country.

Three tests are applied. The first is a turning point test by counting the peaks and troughs in the series and comparing it with the expected number of turning points in a random series.[17] If the series is random, the expected number of turning points 'p' is given by $E(p) = 2/3\ (n-2)$, with variance $V(p) = (16n-29)/20$, where n is the total number of terms in the series (Kendall and Stuart, 1966). Also, the

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[17] A "peak" is a value which is greater than the two neighboring values in a time series. Similarly, a "trough" is a value that is lower than its two neighbors. Peaks and troughs in a time series are called turning points.

mean interval between turning points in a random series is about 1.5 with a variance of about 9/(10n). Against the expected number of turning points at 59.33 for randomness (2x89/3 since n is equal to 91, from 1875-76 to 1965-66), the actual numbers observed in national cereals and rice rainfall index were 66 and 60, respectively. Also, the mean intervals between turning points obtained from the cereals and rice rainfall indices were 1.34 and 1.44, respectively. These values are reasonably close to a series with random nature.

The second test applied examined the distribution of phase lengths. In a random series, the probability of a phase of length 'd' either rising or falling[18] is given by, $2(d^2 + 3d - 1)/d + 3)!$, where $(d + 3)! = 1.2.3---(d + 2)(d + 3)$ (Kendall and Stuart, 1966). If the series is random, the expected number of phases of length 'd' in a series of 'n' terms is given by

$$Nd - 2(n-d-2)(d^2+3d+1)/(d+3)!$$

and the expected number of all possible phase lengths is given by

$$N \doteq 1/3\ (2N-7).$$

Table 10 provides the observed and expected number of different phase lengths in national cereals and rice rainfall index series. To examine the goodness of fit, X^2 (Chi Square) statistic was computed and $\frac{6}{7} X^2$ was compared against the tabulated value for 2 degrees of freedom (Kendall and Stuart, 1966). In both cases, the test for goodness of fit provided a positive answer, suggesting, thereby, that both the index series can be considered as random.

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[18] To define a phase of length d (say, a run up), (d+3) consecutive terms are required, involving a fall from first to second, a rice from second to third, third to fourth---(d+1)th to (d+2)th and a fall from (d+2)th to (d+3)th. In a series of length n, there are only (n-d-2) possible phases of length d.

Finally, the serial correlations are examined. Theoretically, in a random series, the serial correlation r_k[19] is zero for all k except for k=0 for which $r_0 = 1$. In a short series, the observed serial correlations do not strictly assume the theoretical values. They fluctuate because of sampling effects and also they are biased downwards.[20] This is evident from the first 25 serial correlations computed from cereals and rice rainfall index series (Table 11). With the exception of r_{15} and r_{18}, the magnitude of all these coefficients is very close to zero and justifies the assumption of randomness in the rainfall distribution pattern. The reasons for r_{15} and r_{18} to record higher values are difficult to find out; they could be spurious or due to some hidden generating process. Since our short series does not provide scope for probing deeper into the causes for these higher values, we would like to give the benefit of doubt and assume the rainfall indices are randomly distributed.

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[19] For computational purpose, the following formula is used

$$r_k = \frac{\frac{1}{(n-k)} \sum_{i=1}^{n-k} (W_i-\bar{W})(W_{i+k}-\bar{W})}{\frac{1}{n} \sum_{i=1}^{n} (W_i-\bar{W})^2}$$

where $\bar{W} = \frac{1}{n} \sum_{i=1}^{n} W_i$

W = rainfall index

[20] In a random series of large sample size n, $E(r_k) = -(1/n-1)$ and $v(r_k) = 1/n$. Thus, the bias in r_k in a random series is $-(1/n-1)$ while its variance is of the order of n^{-1}.

Table 10. Observed and expected phase lengths in cereals and rice rainfall index

Phase Length	Observed		Expected (for cereals or rice)	X^2-Statistic	
	Cereals	Rice		Cereals	Rice
1	46	35	36.67		
2	16	22	15.95	2.48	3.25
3	3	2	4.54		
Total	65	59	58.33		

Table 11. Serial correlation of all-India cereals and rice rainfall index

Order of Correlation	Cereals	Rice	Order of Correlation	Cereals	Rice
1	-0.00	-0.09	14	0.14	0.15
2	0.08	-0.11	15	-0.30	-0.29
3	0.09	0.14	16	0.05	0.07
4	-0.16	0.01	17	-0.04	-0.03
5	0.01	0.04	18	-0.21	-0.26
6	0.10	0.02	19	0.10	0.11
7	0.04	0.02	20	-0.09	-0.03
8	0.14	0.13	21	0.01	-0.03
9	-0.16	-0.17	22	0.14	-0.01
10	-0.06	-0.11	23	0.06	0.03
11	0.08	0.02	24	0.15	0.19
12	-0.08	-0.07	25	0.03	0.03
13	-0.04	-0.14			

Probable Changes in the Estimating Parameters

The crucial factors in estimating the variations in future cereals and rice production in India owing to rainfall are the distribution pattern of rainfall indices and their effects on production. The question is can we take these as invariant over time and, if not, what adjustment should we make to estimate the variability in future production owing to rainfall?

The indices computed from past rainfall data were a single realization from an unknown population. For each year 't,' the rainfall index W is a random variable with unknown mean and variance and the actual value observed is a single sample realized from this unknown universe. If the universe is, itself, undergoing changes (i.e., if Ws are samples from different populations), there is no way of estimating the parameters from sample observations recorded over time. If, however, we assume the stationarity in mean and variance, it.e, E(W) and V(W) to remain constant for all 't' then under certain conditions it can be shown mathematically that the sample mean and variance computed from the recorded time series data provide their estimates.

The question, therefore, is whether the distribution of rainfall is likely to undergo any change in the future. The answer is, of course, not known. And even if the natural factors remain the same, there are other man-made factors that could disturb the assumption of stationarity. For example, if the countryside is gradually denuded of all forests, both the mean and variability in rainfall indices could undergo changes. The same might also happen if the technique of artificial rain-making becomes practical with wide applicability. Based on current technology and knowledge, however, these possibilities are too remote or are unlikely to have effect. Past data suggest that the assumption of stationarity in mean and variance in rainfall indices, is reasonably valid. We, therefore, agree and assume that for future years, rainfall indices will record the same distribution as observed in the past.

Since the normal weather production in any year is defined as expected production (trend level) corresponding to the average rainfall index 100, the actual production then will be above or below the expected level--according to whether the rainfall index is above or below the average. The question is: Will the probability distribution of production variations in absolute terms (i.e. variations expressed in say, million tons) also remain invariant over time?

We earlier estimated the effect of rainfall on production from past data. Since the rainfall response coefficients are expressed as a percentage of expected production (trend level), the probability distribution of output deviation in absolute terms will be a function of the trend level of production. Thus, if the probability distribution in production variations expressed as a percentage of the trend is assumed to be the same for all future years, the probabilities of the magnitudes of absolute deviations in production will increase with an increase in the level of production. This is one extreme of the situation that is likely to occur if the food grains production grows along the low path.

The future production in India under the high projection is anticipated to grow at a higher rate than that observed in the past. This higher growth rate is to come from an increase in irrigated acreage.

However, an expansion in irrigated acreage tends to reduce the instability in production because of rainfall variations, and the estimated rainfall response coefficients are, therefore, likely to decline over time. If the estimated rainfall response coefficients are agreed to reflect production variations with absolute production at the 1970-71 level and then all assumed to decline at the same rate as production increases (i.e. area under irrigation increases), then the coefficient of variability in production around the trend will also record the same rate of decline. Under such an assumption, the probability distribution of absolute deviations in production will remain constant for all future years and one has to compute the probabilities of absolute deviations in production by using only the 1970-71 estimated normal-weather production.

The probability distribution of the absolute deviations in production, estimated under the high or low path, will be somewhere between these two alternatives, and to compute the distribution of actual variation in production, one has to continuously update the type of analysis made here. To simplify the estimation procedure for reserve stock requirements at different probability levels, we shall consider only the second alternative which provides stationarity in probability distribution of absolute variations in production for all future years. Under such an assumption, the future additional production (assumed under the high or low projection) over the 1970-71 normal-weather production level to meet population and per capita demand growth becomes free from any fluctuation. If the expected value of future production is assumed equal to the corresponding demand, then the production for any future year 't' is

$$X + \Delta Y_t$$

where X is random, E(X) is equal to 1970-71 normal-weather production estimate and ΔY_t is the additional increase in production over the corresponding value (under the high or low projection) based on expected normal-weather production of 1970-71. Since ΔY_t is assumed free from any stochastic component, the domestic supply will equal the corresponding demand only if the former is equal to $E(X) + \Delta Y_t$. However, as X is a random variable, actual availability in year 't' will fluctuate around the corresponding demand. Therefore, in order to stabilize domestic supply around the level of demand the maintenance of stocks will become necessary so that these stocks are released or replenished to reduce the amplitude of fluctuation in X.

Obviously, the results based on the above assumption will provide the minimum stock requirement estimates for the future years. Precise estimates for any year are likely to be above these levels unless the technique of production reduces the intensity of fluctuation around the future production path.

Estimated Requirements for Reserve Stocks

With national rainfall indices as obtained from 1875-76 and production at 1970-71, Table 12 provides year-to-year absolute deviations in cereals and rice production (estimated with the help of Equations 4.1 and 4.2) which would result if the same sequences of cereals and rice rainfall

Table 12. Rain-induced fluctuations in all-India cereals and rice production

With Rainfall Index as	Deviation in Production: Percent of the trend		Deviation in Production: in mil. ton from 1970-71 level		With Rainfall Index as	Deviation in: Percent of the trend	
	Cereals	Rice	Cereals	Rice		Cereals	Rice
1877-78	-3.79	-1.34	-3.51	-.56	1907-08	-12.54	-10.05
-79	+15.76	+17.16	+14.60	7.17	-09	+12.59	11.56
-80	-4.04	-5.31	-3.74	-2.22	-10	-2.65	-.69
-81	-6.82	-6.35	-6.32	-2.65	-11	-0.22	-4.33
-82	+5.85	+4.65	5.42	1.94	-12	-8.14	-4.56
-83	-1.18	-2.73	-1.09	-1.14	-13	+6.88	4.14
-84	-2.24	-1.08	-2.08	-.45	-14	-1.87	2.32
-85	+5.43	+5.43	5.03	2.27	-15	+6.82	1.36
-86	-5.15	-3.11	-4.77	-1.30	-16	-7.63	-4.29
-87	+4.32	+1.76	4.00	0.74	-17	+9.26	5.50
-88	-2.75	-13.66	-2.55	-5.71	-18	-1.73	-1.13
-89	-2.74	17.53	-2.54	7.32	-19	-13.65	-9.89
-90	+5.50	.93	5.10	.39	-20	+18.42	12.83
-91	-0.55	-3.42	-0.51	-1.43	-21	-12.62	-10.28
-92	-7.26	-9.77	-6.73	-4.08	-22	+10.49	10.16
-93	+17.43	+15.34	16.15	6.41	-23	-1.54	-.26
-94	-8.60	-2.72	-7.97	-1.14	-24	-5.71	-11.81
-95	+0.13	-6.07	0.12	-2.52	-25	+5.79	11.96
-96	-6.42	.82	-5.97	.34	-26	-4.17	-3.81
-97	+3.79	1.57	3.51	.66	-27	+4.22	.98
-98	+0.93	-3.29	0.86	-1.37	-28	-2.20	-4.47
-99	+0.52	9.25	0.48	3.86	-29	-3.16	1.90
1900	-10.38	-15.21	-9.62	-6.15	-30	+3.73	2.43
-01	+21.01	17.13	19.46	7.16	-31	-1.36	-1.83
-02	-16.50	-15.26	-15.29	-6.38	-32	+3.17	.83
-03	+8.62	11.28	7.99	4.71	-33	-5.30	-4.36
-04	+2.84	-1.58	2.63	-.66	-34	+9.63	12.45
-05	-9.36	-8.32	-8.70	-3.48	-35	-7.08	-12.21
-06	+3.04	7.91	2.82	3.30	-36	-0.83	3.24
-07	+9.61	3.24	8.90	1.35	-37	+6.46	9.28

Table 12. (Continued)

With Rainfall Index as	Production in mil. ton from 1970-71 level		With Rainfall Index as	Deviation in Production			
				Percent of the trend		in mil. ton from 1970-71 level	
	Cereals	Rice		Cereals	Rice	Cereals	Rice
1877-78	-11.62	-4.20	1937-38	-6.55	-13.24	-6.07	-5.53
-79	11.66	4.83	-39	5.27	11.11	4.88	4.64
-80	-2.45	-.29	-40	-7.36	-9.13	-6.82	-3.81
-81	-0.20	-1.81	-41	6.47	5.85	5.99	2.44
-82	-7.54	-1.91	-42	-5.07	-4.61	-4.70	-1.93
-83	6.37	1.73	-43	8.82	6.09	8.17	2.54
-84	-1.73	.97	-44	-5.29	-2.17	-4.90	-.91
-85	6.32	.57	-45	3.27	-2.23	3.03	-.93
-86	-7.07	-1.79	-46	-5.14	-2.29	-4.76	-.96
-87	8.58	2.30	-47	5.64	+8.66	5.22	3.62
-88	-1.60	-0.47	-48	-2.52	-5.02	-2.33	-2.10
-89	-12.65	-4.13	-49	0	.12	0	.05
-90	17.06	5.36	-50	.51	1.78	.47	.74
-91	-11.69	-4.29	-51	-1.86	-3.31	-1.72	-1.38
-92	9.72	4.24	-52	-5.52	-5.00	-5.11	-2.09
-93	-1.43	-.11	-53	5.83	5.83	5.40	2.44
-94	-5.29	-4.93	-54	7.55	8.92	6.99	3.73
-95	5.36	5.00	-55	-7.07	-10.47	-6.55	-4.37
-96	-3.86	-1.59	-56	6.52	5.66	6.04	2.36
-97	3.91	.41	-57	.08	5.23	.07	2.18
-98	-2.04	-1.87	-58	-10.10	-14.51	-9.36	-6.06
-99	-2.93	.79	-59	7.78	6.83	7.21	2.85
1900	3.46	1.02	-60	-2.04	-1.83	-1.89	-.76
-01	-1.26	-.76	-61	.86	5.59	.80	2.34
-02	2.94	.35	-62	4.04	-.09	3.74	-.04
-03	-4.91	-1.82	-63	-8.54	-9.83	-7.91	-4.11
-04	8.92	5.20	-64	3.93	8.26	3.64	3.45
-05	-6.56	-5.10	-65	3.57	1.99	3.31	.83
-06	-0.77	1.35					
-07	5.98	3.88					

indices were to repeat itself in future. Table 13 provides the frequency distribution of these deviations. There appears to be a roughly 10 percent chance (i.e., once in every ten years) of cereals output recording fluctuations within million tons and about 20 percent chance (i.e. once in every five years) of their recording fluctuations within ±2 million tons. For rice, the chances of fluctuations lying within ±1 and ±2 million tons are roughly once in every four years and once in every two years respectively.

The standard deviations in national cereals and rice production due to rainfall, with production at 1970-71 level, are estimated at 6.8 and 3.3 million tons. Based on the assumption of stationarity mentioned in the previous section, it follows that the average deviations in future cereals and rice production in India are expected to lie within the ranges $\pm$ 6.8 and $\pm$ 3.3 million tons. Also, since the rainfall indices have normal distribution, it follows that variations in production because of rainfall will also be normally distributed. Using the property of the normal distribution we can, therefore, conclude that a reserve stock, equivalent to twice the standard deviation, will be adequate in 95 percent of the cases to offset any individual year's production fluctuation due to rainfall. This suggests the need to have a reserve of about 14 million tons of cereals with about 6 million tons of rice in it. However, a stock at these levels may or may not protect the farmers or consumers if the good or bad years come in sequences. The question, therefore, is how frequent is the occurrence of these sequences and how severe is their impact on production?

Table 13. Frequencies of deviations in production

Deviations in Production (expressed as percentage of the trend or in million tons from 1970-71 production level)	Percentage Frequency			
	When deviations are expressed as percentage of the trend		When deviations are estimated in million tons from the 1970-71 production level	
	Cereals	Rice	Cereals	Rice
< -14.99	1.12	2.25	1.12	-
-14.99 to -12.50	3.37	3.37	1.12	-
-12.49 to -10.00	3.37	6.74	2.25	-
-9.99 to -9.00	1.12	4.49	3.37	-
-8.99 to -8.00	3.37	1.12	1.12	-
-7.99 to -7.00	5.62	0.00	4.50	-
-6.99 to -6.00	3.37	2.25	6.74	3.37
-5.99 to -5.00	7.87	2.25	3.37	3.37
-4.99 to -4.00	2.25	6.74	5.62	8.99
-3.99 to -3.00	2.25	5.62	3.37	2.25
-2.99 to -2.00	7.87	5.62	7.87	5.62
-1.99 to -1.00	6.74	6.74	7.87	14.61
-0.99 to 0.00	4.49	3.37	4.49	13.48
+0.01 to 1.00	6.74	5.62	6.74	13.48
1.01 to 2.00	0.00	6.74	0.00	5.62
2.01 to 3.00	1.12	2.25	3.37	10.11
3.01 to 4.00	7.87	2.25	8.99	6.74
4.01 to 5.00	3.37	3.37	1.12	5.62
5.01 to 6.00	7.87	7.87	8.99	2.25
6.01 to 7.00	5.62	2.25	4.50	1.12
7.01 to 8.00	2.25	1.12	2.25	3.37
8.01 to 9.00	2.25	3.37	4.50	-
9.01 to 10.00	3.37	2.25	1.12	-
10.01 to 12.50	1.12	6.74	1.12	-
12.51 to 15.00	1.12	1.12	1.12	-
> 15.00	4.49	4.49	3.37	-

With an exceptionally bad year, such as 1901-02, cereals and rice production would record deviations of 15.29 and 6.38 million tons, respectfully. Similarly, with an exceptionally good year, such as the one recorded for cereals in 1900-01 and for rice in 1888-89, the corresponding production would record deviations of 19.46 and 7.32 million tons. Thus, to make a liberal provision for any individual best or worst year in the future it will be sufficient to maintain about 17 million tons of cereals with a rice component of about 7 million tons. However, the chances of these types of events occurring are about once in a century and, with such a remote chance, the need to maintain the above levels of stocks can be questioned.

In fact, when we look into the sequences of good or bad years of production, the need to maintain higher levels of stocks appears unnecessary to some extent. With rainfall indices as obtained from 1875-76 and with production at the 1970-71 level, the cumulative production deficits or surpluses that occurred in sequences are given in Table 14. Notice that the sequences of length 2 are more frequent than sequences of other lengths,[21] i.e., two consecutive years of good or bad harvest are more likely than any other prolonged sequence. There are six sequences for cereals, one of length 3 and the rest of length 2, in which the cumulative production deficits or surpluses were above 10 million tons. If we consider the averages of the three worst and the three best sequences then the cumulative production deficits or surpluses could be of the order of -11.5 and 11.6 million

[21] Exact probabilities of these sequences can be obtained from (Feller, 1950).

tons. This suggests the need to have a reserve stock of roughly 12 million tons to take into account most of the worse and best sequences of cereals production.

Similarly, for rice there are five sequences, each of length 2, in which production deficits or surpluses exceeded 5 million tons. If we consider the averages of the two worst and the three best sequences, then the cumulative production deficits or surpluses can generally be of the order of -5.3 and 6.4 million tons. This suggests a reserve stock of about 6 million tons of rice. Thus, to even out most of the worse and best sequences of production, it appears adequate to maintain 12 million tons of cereals plus about half of it in rice reserve.

Tables 12-14 also provide the percent deviations from cereals and rice production trend lines which would result if the same sequences of rainfall indices were to be repeated in the future. From the past record it appears that, in one of every four years or less, the cereals output is likely to record a 3 percent or less deviation from its expected level and, for rice, this deviation is likely to be within 2 percent from the corresponding expected level. Also, the cumulative production deficits or surpluses in any two years from the corresponding expected levels is estimated to exceed a total of 15 percent. Thus, if the intensities of production fluctuations around the trends follows the past patterns then, to meet any contingency of the above types, the future requirements for reserve stocks will increase along with the increase in the level of production. This means all the earlier estimates derived on the assumption of stationarity in absolute deviations in production will grow at a rate commensurate with the rate of increase in production.

The stock requirements suggested here are entirely from the consideration of estimated production fluctuations due to the historical variations in rainfall. As will be shown in the next chapter, various other considerations also are equally important in determining the size of reserve, and the appropriateness for any specific level of reserve for the future can be judged only by examining the costs and benefits that it will accrue to the nation.

Table 14. The cumulative production deficits or surpluses occurred in sequences for cereals and rice

CEREALS

With production fluctuation as occurred in sequences	Cumulative Production Deficit (-) or Surplus (+): When deviations are expressed as percentage of the trend	Cumulative Production Deficit (-) or Surplus (+): When deviations are estimated in mil. tons from the 1970-71 level	Length of the sequence
1879-81	-10.86	-10.06	2
1882-84	-3.42	-3.17	2
1887-89	-5.49	-5.09	2
1890-92	-7.81	-7.24	2
1896-99	+5.24	+4.85	3
1902-04	+11.46	+10.62	2
1905-07	+12.65	+11.72	2
1909-12	-11.01	-10.19	3
1917-19	-15.38	-14.25	2
1922-24	-7.25	-6.72	2
1927-29	-5.36	-4.97	2
1934-36	-7.91	-7.33	2
1947-49	-2.52	-2.33	2
1950-52	-7.38	-6.83	2
1952-54	+13.38	+12.39	2
1955-57	+6.60	+6.11	2
1960-62	+4.90	+4.54	2
1963-65	+7.50	+6.95	2

RICE

With production fluctuation as occurred in sequences	Cumulative Production Deficit (-) or Surplus (+): When deviations are expressed as percentage of the trend	Cumulative Production Deficit (-) or Surplus (+): When deviations are estimated in mil. tons from the 1970-71 level	Length of the Sequence
1879-81	-11.66	-4.82	2
1882-81	-3.81	-1.59	2
1888-90	+18.46	+7.71	2
1890-92	-13.19	-5.51	2
1893-95	-8.79	-3.66	2
1895-97	+2.39	+1.00	2
1903-05	-9.90	-4.14	2
1905-07	+11.15	+4.65	2
1909-12	-9.58	-4.01	2
1912-15	+7.82	+3.27	2
1917-19	-11.02	-4.60	2
1922-24	-12.07	-5.04	2
1928-30	+4.33	+1.81	2
1935-37	+12.52	+5.23	2
1943-46	-6.69	-2.80	2
1948-50	+1.90	+.79	2
1950-52	-8.31	-3.47	2
1952-54	+14.75	+6.17	2
1955-57	+10.89	+4.54	2
1961-63	-9.92	-4.15	2
1963-65	+10.25	+4.28	2

V. EVALUATING THE BUFFER STOCK PROGRAM

A policy maker may state his stabilization objective by specifying the desirable limits of fluctuation either in the level of consumption or in the price or farm income. In general, he will have to operate the program under the limitations of availability of funds and storage capacities. Although operational funds may be readily available, storage capacity is something that must be planned in advance. The level of storage capacity to plan for also depends on the predetermined stabilization level. If it is stated, a probabilistic approach can be used to determine the necessary operational funds. Together, the cost will be substantial and can be justified only against the benefits forthcoming.

A two-stage procedure has been adopted for evaluating the buffer stock program. To determine the storage capacity requirement for future years, storage rules aimed at stabilizing consumption within specified limits are first used to examine the consequences of operating with different storage capacities on price and farm income variations. A simulation approach is then outlined for estimating the costs and benefits of operating the buffer stock program with fixed storage capacities and given storage rules aimed at stabilizing price within specified limits.

Estimation of Storage Capacity Requirements for Stabilizing Consumption

The main objective of the storage program is to reduce the variability in consumption due to output fluctuations by restricting consumption in years of good crops and augmenting it in lean years. Thus, if we consider the quantity Y_t released or withdrawn as a function of the current output X_t, then a simple statistical rule for stock operation can be derived as follows: Choose α such that $Y_t = \alpha(X_t - \mu_n)$, so that the variance σs^2 of consumption $s_t = x_t - y_t$ is reduced. Evidently, α is to be chosen at some preassigned probability level unless the plan is for complete stabilization (α=1) or unless the criterion is stated in terms of the desired variance σs^2 of S_t.

If the distribution of output follows some standard probability model, the value of α can be easily determined from published statistical tables. We have already shown that the probability distribution of output variations due to rainfall follows a normal distribution, $N [\mu_x, \sigma_x]$ and, therefore,

$$Y_t \sim N [0, \alpha \sigma_x]$$

and $$S_t \sim N[\mu_x, (1-\alpha) \sigma_x]$$

For a given percentage deviation in production (say K) from its average, the value of α can then be determined from normal probability distribution tables as follows:

If, Prob. of $\left[\frac{|X_t - \mu_x|}{\sigma x}\right] > K$ is say γ, choose α

such that Prob. of $\left[\frac{|S_t - \mu_n|}{(1-\alpha)\sigma x}\right] > K$ is reduced to some preassigned probability level δ, where $\delta < \gamma$.

Y_t can, of course, become positive or negative and since

$\sum_{t=1}^{n} Y_t \sim N\,[0, (n)^{1/2}\alpha\sigma x]$, it follows that the total amount added to storage after operating the rule for n year is $\sum_{t=1}^{n} Y_t$ with mean zero and standard deviation $(n)^{1/2}\alpha\sigma_n$. Thus, the total stock requirement (Z) to run a successful consumption stabilization program over a period of n years, with the probability of success at ν can be estimated from the normal probability distribution table where

$$\text{Prob. of } \frac{Z}{(n)^{1/2}\alpha\sigma_n} = \nu .$$

It then follows from chapter II that if the supply elasticity, $\varepsilon = 0$

$$C_p = C_x\,(1 - \alpha)/n$$

$$C_r = C_p - C_x$$

where C_x, C_p and C_r are the coefficients of variation in production, price, and farm income.

Tables 15 and 16 provide the estimates for cereals and rice stock requirements, to carry out the consumption stabilization program over two different time periods of 15 and 25 years length under different storage rules and their corresponding implications on price and farm income stability at three different success probability levels (ν) 0.950, 0.975 and 0.990 . The rules are specified by the values of α determined at probability levels δ:0.20, 0.15, 0.10, 0.05 and 0.01. All calculations are based on the assumption of stationarity in mean

Table 15. Implication of different statistical storage rules for cereals[a]

	Without Storage Program	With Storage Program: Probability Levels (δ) 0.20	0.15	0.10	0.05	0.01
1. Storage rule: Value of α	0	0.1942	0.3457	0.4708	0.5877	0.7085
2. Stock requirement for a fifteen year period (mil. tons) with the prob. of success ν at						
a. 0 950	0	8.45	15.04	20.48	25.57	30.83
b. 0.975	0	10.07	17.92	24.41	30.47	36.73
c. 0.990	0	11.95	21.27	28.97	36.17	43.60
3. Stock requirement for a twenty-five year period (mil. tons) with the prob. of success ν at						
a. 0.950	0	10.91	19.42	26.44	33.01	39.80
b. 0.975	0	13.00	23.14	31.51	39.34	47.42
c. 0.990	0	15.43	27.46	37.40	46.69	56.29
4. Coefficient of variations in consumption	7.37	5.94	4.82	3.90	3.04	2.15
5. Coefficient of variations in price when the price elasticity of demand is						
a. 0.45	16.38	13.20	10.72	8.67	6.75	4.78
b. 0.50	14.74	11.88	9.65	7.80	6.08	4.30
c. 0.55	13.40	10.80	8.77	7.09	5.53	3.91
6. Coefficient of variations in farm income when the price elasticity of demand is						
a. 0.45	9.01	5.83	3.35	1.30	0.62	2.60
b. 0.50	7.37	4.51	2.28	0.43	1.29	3.07
c. 0.55	6.03	3.43	1.40	0.28	1.84	3.46

[a] μ_n = 92.64 mil. tons; σx = 6.83 mil. tons; probability of 5 percent variation in cereals output is 0.2488; price elasticity of demand at the mean assumed for the three different levels are 0.45, 0.50, and 0.55, respectively.

Table 16. Implications of following different statistical storage rules for rice[a]

	Without Storage Program	With Storage Program				
		Probability Levels (δ)				
		0.20	0.15	0.10	0.05	0.01
1. Storage rule: Value of α	0	0.2433	0.3855	0.5030	0.6128	0.7262
2. Stock requirement for a fifteen year period (mil. tons) with the prob. of success ν at						
a. 0.950	0	5.08	8.05	10.51	12.80	15.17
b. 0.975	0	6.06	9.60	12.52	15.26	18.08
c. 0.990	0	7.19	11.39	14.86	18.11	21.46
3. Stock requirement for a twenty-five year period (mil. tons) with the prob. of success ν at						
a. 0.950	0	6.56	10.40	13.57	16.53	19.59
b. 0.975	0	7.82	12.39	16.17	19.70	23.34
c. 0.990	0	9.28	14.71	19.19	23.38	27.71
4. Coefficient of variations in consumption	7.85	5.94	4.82	3.90	3.04	2.15
5. Coefficient of variations in price when the price elasticity of demand is						
a. 0.50	15.70	11.88	9.65	7.80	6.08	4.30
b. 0.75	10.46	7.92	6.43	5.20	4.05	2.87
c. 1.00	7.85	5.94	4.82	3.90	3.04	2.15
6. Coefficient of variations in farm income when the price elasticity of demand is						
a. 0.50	7.85	4.03	1.80	0.04	1.77	3.55
b. 0.75	2.61	0.07	1.42	2.65	3.80	4.98
c. 1.00	0	1.91	3.03	3.95	4.81	5.70

[a] μ_n = 41.78 mil. tons; σx = 3.28 mil. tons; probability of 5 percent variation in rice output is 0.2621; price elasticity of demand at the mean assumed for the three different levels are 0.50, 0.75 and 1.00 respectively.

and variance (in absolute terms) of the normally distributed output with mean at the 1970-71 normal weather production levels. The price elasticities of demand for cereals and rice are considered at three different levels around the values estimated in chapter II and the supply elasticities in both the cases are assumed to be zero.

Some quite startling conclusions follow from these statistical rules. Without the storage program, the level of consumption will record a variation of 7.37 percent for cereals and 7.85 percent for rice. With the storage program, the buying and selling operations during good and bad harvest years to reduce variability in consumption will also reduce the variability in farm income. But, the higher the magnitude of the price elasticity of demand, the more rapid will be the convergence of the farm income towards complete stabilization than that of consumption. In fact, corresponding to the cereals price elasticity of demand at 0.45, 0.50, and 0.55, farm income will be completely stabilized by the storage rule with α at 0.55, 0.50, and 0.45. In case of rice, complete farm income stabilization will be achieved by the storage rules with α at 0.50, 0.25 and 0 (i.e. no storage) corresponding to the values of η (price elasticity of demand) at 0.50, 0.75 and 1.00, respectively. However, none of the storage rules at the above levels will completely stabilize price and consumption. Any attempt for further reduction in price and consumption variability beyond the complete farm income stabilization level can be obtained only at the cost of increasing instability in farm income and maintaining huge stocks.

Since the probability distribution of the absolute deviations in production is assumed to remain stationary for the future years, Cx and, hence, all the estimated values of the coefficient of variation in consumption, price, and farm income will decline at the same rate as the production increases. Thus, if the production grows along the high path then, without a storage program, the variabilities in the cereals and rice consumption levels are expected to decline from 7.37 and 7.85 percent in 1971 to 4.71 and 4.53 percent in 1986 and to 3.03 and 2.96 percent in 2001. Under the low projection path, the variabilities in the cereals and rice consumption level will drop to 4.94 and 4.83 percent in 1986 and will further decline to 3.56 and 3.48 percent in 2001. Looking at the stock requirements under different storage rules and those based on the historical analysis, it seems appropriate to have a maximum storage capacity of 15 to 21 million tons cereals and follow the storage rules aimed at stabilizing consumption with about 3 percent variation. For rice, it seems appropriate to have a maximum storage capacity of 7 to 9 million tons and follow the storage rules aimed at stabilizing consumption with about 3 percent variation.

One thing apparent from these results is that, contrary to the usual belief, a storage program with a financial constraint for maintaining large stocks will benefit the producers more than the consumers.

A Simulation Approach for Evaluating the Buffer Stock Program

Suppose now that the future production plans are such that under normal-weather conditions annual production approximately equals corresponding demand. Also, suppose that the intention is to keep price within two specified limits over a given time period and with a given storage capacity. What will be the corresponding costs and benefits in running the program over the entire period?

Because the magnitude of output fluctuation for any year is uncertain, the intentions of the buffer stock agency may or may not be realized throughout the period. It is constrained by available grain in storage or available empty space in storage which, in turn, is a function of the storage rule and the sequential occurrance of the magnitude of output fluctuation in prior years. For any year, the storage activity is thus determined by the level of production, storage rule, and the storage activity in preceding years.

It is now clear that the costs and benefits of the buffer stock program aimed at a desired level of stabilization will be governed by the manner in which the time-ordered production sets occur. Because future production fluctuation cannot be predicted accurately, the determination of costs and benefits of a buffer stock scheme also cannot be precise. These can only be expressed within some confidence limits. To do this, the same buffer stock operation scheme is to be repeated over a large number of sample production data sets.

Time-ordered production sets for the future years can be generated by drawing sets of random samples from the normally distributed population of rainfall indices and estimating the magnitudes of their effects around the future production path. Given Equations 4.1 and 4.2, the procedure for generating the future production sets will then run as follows: 1) draw a random sample of rainfall indices for the future period under consideration from the normally distributed population of rainfall indices with mean 100 and standard deviation as estimated; 2) using the sample values of current and previous year's rainfall indices, determine, for each year t, the percentage deviation in production from the normal-weather production trend line; and 3) with the assumption of stationarity, as mentioned earlier, determine the deviation in million tons and adjust the t^{th} year's anticipated normal-weather production level accordingly.

The evaluation of the buffer stock program for any specified future period can then proceed from a large number of sequentially ordered production sets thus generated by considering different storage rules and computing in each case, the discounted present value of various benefits and costs for each production set; and, finally determining their expected values and standard deviations by combining the estimates derived from all the sample sets.

Since the accent in buffer stock operation is more towards protection of consumers' interest, it would be appropriate to specify the storage rules with variables of direct concern to the consumers.

This can be done by specifying permissible fluctuation limits in price or quantity supplied for consumption. Suppose the rule specifies that, over the entire period, prices should remain within a given range. With price elasticity of demand known, this is equivalent to saying that fluctuations in supply should not exceed certain limits.

Storage rule expresses the intention of the policy maker, consummation of which is conditioned by the particular storage scheme adopted. Different types of storage schemes can be considered. Generally, any scheme will require specification of two parameters -- an initial level of stock with which to start the program and the maximum accomodation available for storage. Since the first year of operation could as well be a bad year, an initial stock is necessary. Also, as storage accomodation cannot be expanded at short notice, maximum storage capacity needs to be specified in advance. For the purpose of illustration, we shall assume that the operation begins with an initial stock equal to the given maximum storage capacity and consider, for a given storage rule, the following three different types of storage schemes: A) Stock operation is confined only to the domestic markets and no foreign trade on grains is allowed; also, the opening stock for the second and subsequent years can be zero. B) Foreign trade in grains is allowed to attain the desired level of stabilization; opening stock for the second and subsequent years can be zero. C) This scheme remains basically the same as the second one but the opening stock for the second and subsequent years is not allowed to fall below a certain level.

Step-wise computations of the storage activities under each of the above storage schemes are outlined for a typical sequentially generated sample production set i (i=1,2..,k) for a period of length n.

X_{ist} = Normal weather production estimates assumed equal to corresponding demand (t=1,2...,n).

$\pm QF_{ist}$ = Storage rule for the year t. Given the intention to limit price fluctuation at ¶ percent of the equilibrium price $\bar{P}$ and the price elasticity of demand at the mean η, $|\pm QF_{ist}|$ = η ¶ X_{ist}, and $\pm QF_{ist}$ provide the permissible limits of fluctuations around X_{ist}.

QF_{irt} = Deviation from X_{ist}, estimated with the help of the crop-rainfall relationship given in the previous chapter from the i^th^ sample rainfall index set.

QS_{idt} = Desired procurement (+) or release (-) of grains to follow the storage rule. QS_{idt} is of the same sign as QF_{irt} with magnitude

$$|QS_{idt}| = |QF_{irt}| - |\pm QF_{ist}|, \text{ if } |QF_{irt}| > |\pm QF_{ist}|$$
$$= 0 \text{ otherwise.}$$

QS_{ibt} = Opening stock under the storage scheme. In the first year of operation, QS_{ibt} is assumed equal to M_1, the maximum storage capacity. For subsequent years

$$M_2 \leq QS_{ib\ t+1} = QS_{ibt} + QS_{irt} \leq M_1$$

where M_2 is the minimum opening stock requirement and QS_{irt} is the actual amount of grain stored (+) or relased (-) under the scheme. Note that QS_{irt} is different from QS_{idt} as the latter is only an expressed desire of the policy maker. M_2 is assumed zero for the storage schemes of the type A and B. Therefore,

i) If $QS_{idt} \leq 0$, $QS_{irt} \leq 0$ and

$$|QS_{irt}| = \text{Min. of } [(QS_{ibt} - M_2), |QS_{idt}|]$$

ii) If $QS_{idt} \geq 0$, $QS_{irt} \geq 0$ and

$$|QS_{irt}| = \text{Min. of } [(M_1 - QS_{ibt}), |QS_{idt}|]$$

IE_{it} = Import (+) or export (-) under the storage scheme. IE_{it} is equal to $QS_{irt} - QS_{idt}$. Also, for scheme A, $IE_{it} = 0$.

To evaluate the buffer stock program under different storage schemes, we shall consider several evaluation indicators. In what follows, the evaluation will center around estimation of the expected value and standard deviation of a number of indicators suitable for comparing alternative buffer stock schemes. Also, for each scheme we shall consider an initial capital investment for storage construction and purchase of grains as required. With the cost for storage construction C per unit, initial capital investment will be assumed equal to M_1 $(\bar{P}+C)$.

If P_{it} and P_{it}' be the free market prices at the purchasing center, with and without the storage schemes and $\bar{P}$ the equilibrium price around which stabilization is sought, then

$$P_{it}' = \bar{P}\left[1 - \frac{(QF_{irt} - QS_{irt} + IE_{it})}{\eta . X_{ist}}\right] \quad \text{and}$$

$$P_{it}' = \bar{P}\left[1 - \frac{QF_{irt}}{\eta X_{ist}}\right]$$

where QF_{irt}, QS_{irt}, and IE_{it} are taken with their appropriate signs. With the discount factor α, we first present the computation of the indicators from the i^{th} sample set, where each set being of length n years (t=1,2...,n):

1) Average Percent Deviation of Price from the Equilibrium Level (I_{1i}):

$$I_{1i} = \left[\frac{1}{n} \sum_{t=1}^{n} \left\{ 100\ (P_{it} - \bar{P})/\bar{P} \right\}^2 \right]^{1/2}$$

on simplification, I_{1i} will be independent of $\bar{P}$.

2) Average Percent Deviation of Farm Income from the Trend (I_{2i}):

$$I_{2i} = \left[\frac{1}{n} \sum_{t=1}^{n} \left\{ 100\ (P_{it} X_{ist} + P_{it} \cdot QF_{irt} - \bar{P} \cdot X_{ist})/\bar{P}X_{ist} \right\}^2 \right]^{1/2}$$

on simplification, I_{2i} will also be independent of $\bar{P}$.

3) Average Size of Opening Stock (I_{3i}):

$$I_{3i} = \frac{1}{n} \sum_{t=1}^{n} (QS_{ibt} - QS_{irt})$$

4) Total Imports (I_{4i}) and Total Exports (I'_{4i}):

$$I_{4i} = \text{total imports} = \sum_{t=1}^{n} IE_{it},\ \text{if } IE_{it} > 0$$

$$I'_{4i} = \text{total exports} = \sum_{t=1}^{n} IE_{it},\ \text{if } IE_{it} < 0.$$

5) Present Value of Imports (I_{5i}) and Exports (I'_{5i}):

Assuming the value per unit of imports and exports at $\bar{P}'$ and $\bar{P}''$

$$I_{5i} = \text{present value of total imports} = -\bar{P}' \sum_{t=1}^{n} \alpha^{t-1} IE_{it},\ \text{if } IE_{it} > 0$$

$$I'_{5i} = \text{present value of total exports} = -\bar{P}'' \sum^{n} \alpha^{t-1} IE_{it},\ \text{if } IE_{it} < 0$$

6) Change in Farm Income due to storage in t^{th} year (I_{6it})

$$I_{6it} = (P_{it} - P'_{it})\,(X_{ist} + QF_{rit})$$

and the present value of changes in farm income from the i^{th} sample set (I6i)

$$I_{6i} = \sum_{t=1}^{n} \alpha^{t-1} I_{6it}$$

7) Present Value of Net Financial Benefits in Stock Operation from Domestic Source (I_{7i}):

Let $P_{it} + C_1$ be the financial cost per unit for purchasing and storing the grain and $P_{it} + C_2$ be the financial benefit per unit (price minus handling and other charges) for selling grain from the buffer.

Then, for the t^{th} year,

$$I_{7it} = \text{financial cost} = -|QS_{irt}|.(P_{it}+C_1),\ \text{if}\ QS_{irt} > 0$$

$$I_{7it} = \text{financial benefit} = |QS_{irt}|\ (P_{it}+C_2),\ \text{if}\ QS_{irt} < 0.$$

and the present value of net financial benefits from the i^{th} sample set,

$I_{7i} = \sum_{t=1}^{n} \alpha^{t-1} I_{7it}$, I_{7it} may be positive or negative or zero. Evidently, the values of the indicators will be different for different sample production sets. For evaluating the buffer stock program under different storage schemes, one will, therefore, have to consider the expected value and standard deviation of the indicators, estimated from the k^{th} sample production sets.

For any of the above indicator I_j, these are thus, given by,

$$\text{Expected Value} = \frac{1}{k} \sum_{i=1}^{k} I_{ji}, \text{ and}$$

$$\text{Standard Deviation} = \left[\frac{1}{k(k-1)}\left(\sum_{i=1}^{k} I_{ji}^{2} - k\,\bar{I}_{j}^{2}\right)\right]^{1/2}$$

$$\text{where } \bar{I}_j = \frac{1}{k}\sum_{i=1}^{k} I_{ji}$$

Costs and Benefits in Buffer Stock Operation

Table 17 illustrates the calculations involved in evaluating a buffer stock program over a 15-year period. Column 2 (X_{ist}) provides an annual projected normal-weather cereals production estimates for the 15-year period. If normal weather prevails over the entire period, annual production is expected to equal corresponding demand, and the price to remain stable. In reality, the situation will be different and prices will record fluctuations. The desire is to keep the price fluctuations throughout the period within a range of $\pm$ 2 percent of the equilibrium price. With price elasticity of demand constant at -0.45, the above intention provides the storage rule and sets the permissible limits of fluctuation ($\pm QF_{ist}$) around the supply (production) trend line (col. 3). Actual fluctuations (QF_{irt}) around the trend line, generated by a sample rainfall index set and Equation 4.1 is shown in col. 4. The desired procurement or release ($\pm QS_{idt}$) to follow the storage rule is then determined (col. 5).

Columns 6-7, 8-10 and 11-13 provide details of the buffer stock operation under the three storage schemes. To illustrate, the maximum storage capacity is assumed at 3 million tons for all the schemes. The computations are self-explanatory. Scheme A does not ensure stabilization up to the desired level for all the years. Schemes B and

Table 17. Illustration of buffer stock operation under different storage schemes (million tons)

1969-70	Projected normal-weather production	Desired permissible fluctuation	Actual fluctuation	Desired Procurement (+) or release (-)	Scheme A		Scheme B			Scheme C		
					Opening stock	Stored (+) or released (-)	Opening stock	Stored (+) or released (-)	Import (+) or export (-)	Opening stock	Stored (+) or released (-)	Import (+) or export (-)
	X_{ist}	$\pm QF_{ist}$	QF_{irt}	QS_{idt}	QS_{ibt}	QS_{irt}	QS_{ibt}	QS_{irt}	IE_{it}	QS_{ibt}	QS_{irt}	IE_{it}
1	2	3	4	5	6	7	8	9	10	11	12	13
1969-70	92.13	0.83	-5.78	-4.95	3.00	-3.00*	3.00	-3.00	1.95	3.00	-2.00	2.95
1970-71	97.58	0.88	2.67	1.79	0.00	1.79	0.00	1.79	-	1.00	1.79	-
1971-72	103.36	0.93	-0.45	-	1.79	-	1.79	-	-	2.79	-	-
1972-73	109.48	0.98	2.14	1.16	1.79	1.16	1.79	1.16	-	2.79	0.21	-0.95
1973-74	115.96	1.04	2.41	1.37	2.95	0.05*	2.95	0.05	-1.32	3.00	-	-1.37
1974-75	120.92	1.09	4.06	2.97	3.00	-*	3.00	-	-2.97	3.00	-	-2.97
1975-76	126.09	1.13	-1.15	-0.02	3.00	-0.02	3.00	-0.02	-	3.00	-0.02	-
1976-77	131.49	1.18	-3.07	-1.89	2.98	-1.89	2.98	-1.89	-	2.98	-1.89	-
1977-78	137.11	1.23	2.31	1.08	1.09	1.08	1.09	1.08	-	1.09	1.08	-
1978-79	142.98	1.29	0.29	-	2.17	-	2.17	-	-	2.17	-	-
1979-80	149.41	1.34	-3.51	-2.17	2.17	-2.17	2.17	-2.17	-	2.17	-1.17	1.00
1980-81	156.13	1.40	3.70	2.30	0.00	2.30	0.00	2.30	-	1.00	2.00	-0.30
1981-82	163.15	1.47	-0.18	-	2.30	-	2.30	-	-	3.00	-	-
1982-83	170.48	1.53	-2.30	-0.77	2.30	-0.77	2.30	-0.77	-	3.00	-0.77	-
1983-84	178.15	1.60	2.16	0.56	1.53	0.56	1.53	0.56	-	2.23	0.56	-

*Stabilization up to the desired level not achieved.

C guarantee it through both imports and exports. The frequency and volume of imports and exports under Scheme 7 are larger than under Scheme 2 as in the former opening stock in any year is not allowed to fall below 1 million tons.

Let $\bar{P}$, $\bar{P}'$ and $\bar{P}''$ be Rs. 800, 610 and Rs. 500 per ton, C_1 and C_2 each equal to Rs. 160 per ton and α equal to 0.93 (corresponding to a 7 percent interest rate). The values of the indicators corresponding to the sample illustration given in Table 17 would then be as given in Table 18. The expected values of the indicators will thus depend not only on the sample production sets but also on the selected values of the various parameters entering into the computation.

Table 18. Sample illustration of storage benefits

Indicator	Unit	Without Storage	With Storage A	With Storage B	With Storage C
I_{1i}	percent	5.44	3.25	1.80	1.80
I_{2i}	percent	2.52	1.39	1.28	1.28
I_{3i}	mil. tons	-	1.94	1.94	2.40
I_{4i}	mil. tons	-	-	1.95	3.95
I'_{4i}	mil. tons	-	-	-4.29	-5.59
I_{5i}	Rs. mil.	-	-	-11.90	-21.09
I'_{5i}	Rs. mil.	-	-	1906	2388
I_{6i}	Rs. mil.	-	-1196	1278	1278
I_{7i}	Rs. mil.	-	1252	1138	569

To assess the financial implications of running a 15-year buffer stock program, covering the Fourth, Fifth, and Sixth Five-Year Plan periods of India (1969-70 through 1983-84), the simulation exercise was carried out in 1971 by selecting a range of values for the parameters around the prevailing levels (Table 19). Projected normal-weather production estimates for each of the 15-year periods were assumed equal to corresponding demands with production rising from the 1968-69 normal-weather estimate of 86.98 million tons of cereals and 41.07 million tons of rice to the corresponding levels of 115.96 and 59.72, 142.98 and 73.32, and 178.15 and 91.11 million tons, respectively, in 1973-74, 1978-79, and 1983-84. Using the estimated distribution pattern of the rainfall indices and Equations 4.1 and 4.2, 500 sample production sets were generated separately for the cereals group and rice around their respective projected growth paths and these were then used for estimating the above indicators for the cereals group and rice separately. Also, because the financial costs and benefits in buffer stock operation depend heavily upon the location where the grain is stored, four possibilities were considered: (a) Grains stored at the consuming centers and sold also at these centers at a fixed price, 5 percent higher than $\bar{P}$ (e.g. selling through the Fair Price Shops). The financial cost and benefit per ton were taken as Rs. $(P_{it}+160)$ and Rs. $(1.05\ \bar{P} - 50)$. (b) Grains stored at the consuming centers and sold in the retail markets of these centers at a price to cover the total costs of stock operation. The financial cost and benefit per ton were each taken as Rs. $(P_{it}+160)$. (c) Grains stored at the consuming centers but sold in these centers at a price to compete with the free wholesale market prices. The financial cost and benefit per ton were taken as Rs. (P_{it}+160) and Rs. (P_{it}-50). (d) Grains stored at the purchasing centers and also sold in these centers at a price to compete with the free wholesale market prices. The financial cost and benefit per ton were taken as (P_{it}+100) and (P_{it}-50).

Table 19. Selected values of the parameters

Parameter	Cereals	Rice
C (Rs/ton)	150	150
$\bar{P}$ (Rs/ton)	750,800,850	800,850,900
η (Percent)	-0.45	-0.75
¶ (Percent)	2,3,4,5	2,3,4,5
α (Percent)	93.4579	93.4579
$\begin{bmatrix} M_1 \\ M_2 \end{bmatrix}$ (mil. ton)	$\begin{bmatrix} 5.0 \\ 2.0 \end{bmatrix}, \begin{bmatrix} 7.0 \\ 2.5 \end{bmatrix}, \begin{bmatrix} 9.0 \\ 3.0 \end{bmatrix}, \begin{bmatrix} 11.0 \\ 3.5 \end{bmatrix}$	$\begin{bmatrix} 2.0 \\ 0.5 \end{bmatrix}, \begin{bmatrix} 3.0 \\ 1.0 \end{bmatrix}, \begin{bmatrix} 4.0 \\ 1.5 \end{bmatrix}, \begin{bmatrix} 5.0 \\ 2.0 \end{bmatrix}$
$\bar{P}'$ (Rs/ton)	610	1010
$\bar{P}''$(Rs/ton)	500	900
$\begin{bmatrix} P_{it}+C_1 \\ P_{it}+C_2 \end{bmatrix}$ (Rs/ton)	(a) $\begin{bmatrix} P_{it}+160 \\ 1.05\bar{P}-50 \end{bmatrix}$ (b) $\begin{bmatrix} P_{it}+160 \\ P_{it}+160 \end{bmatrix}$ (c) $\begin{bmatrix} P_{it}+160 \\ P_{it}-50 \end{bmatrix}$ (d) $\begin{bmatrix} P_{it}+100 \\ P_{it}-50 \end{bmatrix}$	(a) $\begin{bmatrix} P_{it}+160 \\ 1.05\bar{P}-50 \end{bmatrix}$ (b) $\begin{bmatrix} P_{it}+160 \\ P_{it}+160 \end{bmatrix}$ (c) $\begin{bmatrix} P_{it}+160 \\ P_{it}-50 \end{bmatrix}$ (d) $\begin{bmatrix} P_{it}+160 \\ P_{it}-50 \end{bmatrix}$

Tables 20 and 21 provide the expected values of the first five indicators obtained from the simulation run for the period 1969-70 through 1983-84 when different storage rules and schemes were adopted for the cereals as a whole and rice (for standard deviations of the estimates, see Appendices Table D11 and Table D12). With no storage program, the sample estimates of average deviation in price and farm

Table 20. Expected values of storage benefits for cereals: stabilization around any specified price $\bar{P}$ [a]

		Scheme-A				Scheme-B				Scheme-C			
		$M_1=5.0$ $M_2=0.0$	$M_1=7.0$ $M_2=0.0$	$M_1=9.0$ $M_2=0.0$	$M_1=11.0$ $M_2=0.0$	$M_1=5.0$ $M_2=0.0$	$M_1=7.0$ $M_2=0.0$	$M_1=9.0$ $M_2=0.0$	$M_1=11.0$ $M_2=0.0$	$M_1=5.0$ $M_2=2.0$	$M_1=7.0$ $M_2=2.5$	$M_1=9.0$ $M_2=3.0$	$M_1=11.0$ $M_2=3.5$
	Price Dev.[b]	3.21	2.98	2.89	2.86	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
	Farm Income Dev.[b]	1.62	1.67	1.69	1.69	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
(A)	Ave. Opt. Stock[c]	3.20	4.84	6.68	8.63	3.20	4.84	6.68	8.63	3.81	5.33	6.99	8.78
	Total Imports[c]	-	-	-	-	2.11	0.89	0.34	0.11	4.52	2.57	1.38	0.71
	Total Exports[c]	-	-	-	-	-4.67	-4.26	-4.20	-4.19	-6.11	-4.89	-4.39	-4.23
	Price Dev.[b]	3.62	3.47	3.42	3.40	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55
	Farm Income Dev.[b]	1.69	1.69	1.69	1.69	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
(B)	Ave. Opt. Stock[c]	3.32	5.06	6.97	8.95	3.32	5.06	6.97	8.95	3.85	5.43	7.16	9.02
	Total Imports[c]	-	-	-	-	1.31	0.48	0.15	0.04	3.10	1.65	0.80	0.36
	Total Exports[c]	-	-	-	-	-3.83	-3.64	-3.63	-3.62	-4.70	-3.96	-3.69	-3.63
	Price Dev.[b]	4.03	3.94	3.91	3.91	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
	Farm Income Dev.[b]	1.89	1.88	1.87	1.87	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
(C)	Ave. Opt. Stock[c]	3.49	5.31	7.27	9.26	3.49	5.31	7.27	9.26	3.92	5.57	7.37	9.29
	Total Imports[c]	-	-	-	-	0.76	0.23	0.06	0.01	2.07	0.99	0.43	0.17
	Total Exports[c]	-	-	-	-	-3.18	-3.12	-3.11	-3.11	-3.69	-3.25	-3.13	-3.11
	Price Dev.[b]	4.41	4.36	4.35	4.34	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
	Farm Income Dev.[b]	2.13	2.12	2.11	2.11	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
(D)	Ave. Opt. Stock[c]	3.68	5.57	7.56	9.55	3.68	5.57	7.56	9.55	4.00	5.73	7.61	9.56
	Total Imports[c]	-	-	-	-	0.40	0.10	0.02	Neg.	1.30	0.55	0.20	0.07
	Total Exports[c]	-	-	-	-	-2.64	-2.61	-2.61	-2.61	-2.90	-2.66	-2.62	-2.61

[a]Storage rules aimed at limiting price fluctuations at 2,3,4, and 5 percent of the desired mean price level $\bar{P}$ are denoted by (A), (B), (C), and (D) respectively. With no storage program, the sample estimates of average deviation in price and farm income are obtained as 5.76 and 3.18 percent respectively. For standard deviations of the estimates, see Appendix Table D11.

[b]Expressed in percentages.

[c]Expressed in million tons.

Table 21. Expected values of storage benefits for rice: stabilization around any specified price $\bar{P}$[a]

		Scheme-A				Scheme-B				Scheme-C			
		M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.5	M_1=3.0 M_2=1.0	M_1=4.0 M_2=1.5	M_1=5.0 M_2=2.0
	Price Dev.[b]	1.53	1.52	1.51	1.51	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
	Farm Income Dev.[b]	0.38	0.39	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
(A)	Ave. Opt. Stock[c]	1.51	2.46	3.44	4.44	1.51	2.46	3.44	4.44	1.58	2.51	3.48	4.46
	Total Imports[c]	-	-	-	-	0.19	0.05	0.01	Neg.	0.37	0.19	0.10	0.05
	Total Exports[c]	-	-	-	-	-1.03	-1.01	-1.01	-1.01	-1.03	-1.03	-1.02	-1.01
	Price Dev.[b]	1.72	1.72	1.72	1.72	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
	Farm Income Dev.[b]	0.42	0.42	0.42	0.42	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
(B)	Ave. Opt. Stock[c]	1.77	2.76	3.76	4.76	1.77	2.76	3.76	4.76	1.79	2.77	3.76	4.76
	Total Imports[c]	-	-	-	-	0.02	Neg.	Neg.	Neg.	0.06	0.02	0.01	Neg.
	Total Exports[c]	-	-	-	-	-0.41	-0.40	-0.40	-0.40	-0.41	-0.41	-0.40	-0.40
	Price Dev.[b]	1.79	1.79	1.79	1.79	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77
	Farm Income Dev.[b]	0.44	0.44	0.44	0.44	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
(C)	Ave. Opt. Stock[c]	1.92	2.92	3.92	4.92	1.92	2.92	3.92	4.92	1.92	2.92	3.92	4.92
	Total Imports[c]	-	-	-	-	Neg.	Neg.	Neg.	Neg.	0.01	Neg.	Neg.	Neg.
	Total Exports[c]	-	-	-	-	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12
	Price Dev.[b]	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81
	Farm Income Dev.[b]	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
(D)	Ave. Opt. Dev.[b]	1.98	2.98	3.98	4.98	1.98	2.98	3.98	4.98	1.98	2.98	3.98	4.98
	Total Imports[c]	-	-	-	-	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
	Total Exports[c]	-	-	-	-	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02

[a]Storage rules aimed at limiting price fluctuations at 2, 3, 4, and 5 percent of the desired mean price level $\bar{P}$ are denoted by (A), (B), (C), and (D), respectively. With no storage program, the sample estimates of average deviation in price and farm income are obtained as 1.82 and 0.46 percent respectively. For standard deviations of the estimates, see Appendix Table D12.

[b]Expressed in percentages.

[c]Expressed in million tons.

income due to cereals output fluctuations were obtained as 5.76 and 3.18 percent, respectively. For rice, these were 1.82 and 0.46 percent, respectively.

Under Scheme A, when the operation of releasing or replenishing the stocks was entirely made from the domestic sources, both the price and farm income fluctuations declined but the declinations, even by doubling the size of the storage program, were not as spectacular as is usually believed. This was more true for rice because of its substitutability with other food crops, as evident from its high price elasticity of demand. In fact, from the estimated results it appeared that: (1) for cereals, a 7 million ton storage program would be adequate to keep the price and farm income fluctuations below 3 and 2 percent, respectively. With a 5 million ton storage program, it would be possible to keep the price fluctuations below 4 percent while maintaining farm income fluctuations below 2 percent level; and (2) for rice, a 2 million ton storage program would be more than adequate to keep the price and farm income fluctuations below 2 and 1 percent, respectively. In fact, due to the high price elasticity of demand, a large rice buffer appeared not only unnecessary but also undesirable because increasing the size of the storage program has little effect on reducing price and farm income fluctuations.

For a given storage rule, if Scheme B or C was followed, price and farm income fluctuations settled down to slumbering levels for all sizes of the storage program. However, the magnitudes of imports and exports varied not only with the storage rule but also with the size of the storage program. Also, as expected, the volume of imports and exports under Scheme C was more than under B because of the minimum stock requirement restriction. Clearly, Scheme B or C would be preferable to A. In practice, however, the success of the stock operation under either of these two schemes with a limited storage capacity would depend upon the import and export opportunities.

Since the good and bad harvests are equally probable, the estimates of total volume of imports and exports over the entire period should be approximately of the same order. The sample estimates of total exports under different storage rules were higher than the corresponding imports owing to the assumption of an initial grain reserve for launching the storage program. The need for imports arises only if the initial reserve, augmented by stock accumulation under the capacity constraint, fails to meet the shortfalls below the stability requirement. Evidently, the larger the stock-on-hand, the lesser would be the need to import. As such, the volume of total imports declined more rapidly with the increase in the size of the initial reserve than the corresponding exports in the sample calculations.

With the cost of stock operation at the 1971 level, the financial consequences for adopting different storage rules and schemes at varying levels of storage capacity are shown in Tables 22 and 23 (for standard deviations of the estimates, see Appendices Table D1 and Table D2). With a beginning stock equal to the maximum storage capacity. If

Table 22. Expected present values of storage benefits for cereals (Rs. million); stabilization around $\bar{P}$=Rs. 800 per ton[a]

	Scheme-A				Scheme-B				Scheme-C			
	$M_1=5.0$ $M_2=0.0$	$M_1=7.0$ $M_2=0.0$	$M_1=9.0$ $M_2=0.0$	$M_1=11.0$ $M_2=0.0$	$M_1=5.0$ $M_2=0.0$	$M_1=7.0$ $M_2=0.0$	$M_1=9.0$ $M_2=0.0$	$M_1=11.0$ $M_2=0.0$	$M_1=5.0$ $M_2=2.0$	$M_1=7.0$ $M_2=2.5$	$M_1=9.0$ $M_2=3.0$	$M_1=11.0$ $M_2=3.5$
Initial Inv.	-4,750	-6,650	-8,550	-10,450	-4,750	-6,650	-8,550	-10,450	-4,750	-6,650	-8,550	-10,450
Imports	-	-	-	-	-776	-301	-104	-33	-1,767	-963	-490	-233
Exports	-	-	-	-	1,744	1,630	1,613	1,612	2,167	1,809	1,663	1,621
Δ Farm Inc.	-3,082	-3,982	-4,469	-4,663	1,221	1,221	1,221	1,221	1,221	1,221	1,221	1,221
(A) Fin. Ben.[b]	1,029	1,422	1,644	1,733	1,332	1,772	2,012	2,107	765	1,197	1,574	1,848
Fin. Ben.[c]	2,367	2,880	3,152	3,260	2,282	2,828	3,111	3,222	1,494	2,105	2,588	2,919
Fin. Ben.[d]	900	1,249	1,454	1,537	815	1,198	1,413	1,500	369	703	1,023	1,265
Fin. Ben.[e]	1,188	1,551	1,758	1,841	1,105	1,500	1,717	1,804	606	983	1,321	1,568
Imports	-	-	-	-	-477	-158	-47	-12	-1,222	-616	-280	-117
Exports	-	-	-	-	1,444	1,392	1,389	1,389	1,703	1,483	1,406	1,390
Δ Farm Inc.	-3,002	-3,692	-3,990	-4,087	1,041	1,041	1,041	1,041	1,041	1,041	1,041	1,041
(B) Fin. Ben.[b]	1,143	1,454	1,592	1,637	1,392	1,734	1,881	1,929	852	1,272	1,592	1,786
Fin. Ben.[c]	2,261	2,657	2,825	2,880	2,205	2,621	2,795	2,851	1,488	2,052	2,451	2,684
Fin. Ben.[d]	1,076	1,363	1,492	1,535	1,020	1,327	1,462	1,506	560	915	1,198	1,375
Fin. Ben.[e]	1,291	1,584	1,713	1,756	1,234	1,548	1,683	1,727	743	1,125	1,417	1,596
Imports	-	-	-	-	-275	-77	-19	-4	-821	-369	-148	-54
Exports	-	-	-	-	1,207	1,188	1,187	1,187	1,359	1,225	1,192	1,188
Δ Farm Inc.	-2,828	-3,303	-3,462	-3,503	908	908	908	908	908	908	908	908
(C) Fin. Ben.[b]	1,171	1,390	1,464	1,483	1,371	1,608	1,686	1,707	900	1,275	1,517	1,639
Fin. Ben.[c]	2,084	2,359	2,450	2,473	2,048	2,335	2,428	2,452	1,442	1,929	2,226	2,372
Fin. Ben.[d]	1,148	1,355	1,426	1,444	1,112	1,330	1,404	1,423	694	1,025	1,246	1,360
Fin. Ben.[e]	1,302	1,511	1,581	1,600	1,266	1,486	1,559	1,578	829	1,176	1,402	1,516
Imports	-	-	-	-	-147	-32	-8	-1	-521	-204	-71	-22
Exports	-	-	-	-	1,001	994	994	994	1,081	1,008	995	994
Δ Farm Inc.	-2,559	-2,848	-2,914	-2,933	775	775	775	775	775	775	775	775
(D) Fin. Ben.[b]	1,119	1,254	1,285	1,293	1,275	1,420	1,453	1,462	905	1,208	1,368	1,433
Fin. Ben.[c]	1,848	2,017	2,055	2,066	1,825	2,000	2,040	2,051	1,357	1,743	1,938	2,016
Fin. Ben.[d]	1,126	1,255	1,285	1,293	1,103	1,238	1,269	1,278	764	1,040	1,190	1,251
Fin. Ben.[e]	1,231	1,361	1,391	1,399	1,208	1,345	1,376	1,384	860	1,145	1,296	1,357

[a]Storage rules aimed at limiting price fluctuations at 2, 3, 4 and 5 percent of the desired mean price $\bar{P}$=Rs. 800 per ton are denoted by (A), (B), (C) and (D) respectively. For standard deviations of the estimates, see Appendix Table D1.

[b]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[e]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table 23. Expected present values of storage benefits for rice (Rs. million): stabilization around $\bar{P}$=RS. 850 per ton[a]

		Scheme-A				Scheme-B				Scheme-C			
		M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.5	M_1=3.0 M_2=1.0	M_1=4.0 M_2=1.5	M_1=5.0 M_2=2.0
	Initial Inv.	-2,000	-3,000	-4,000	-5,000	-2,000	-3,000	-4,000	-5,000	-2,000	-3,000	-4,000	-5,000
	Imports	-	-	-	-	-126	-28	-6	Neg.	-250	-126	-60	-28
	Exports	-	-	-	-	699	688	686	686	728	699	690	688
	Δ Farm Inc.	-653	-745	-768	-773	116	116	116	116	116	116	116	116
(A)	Fin. Ben[b]	444	514	531	535	501	575	594	598	423	501	550	575
	Fin. Ben.[c]	662	748	769	774	658	746	767	772	564	658	716	746
	Fin. Ben.[d]	416	482	498	502	413	480	497	500	344	413	456	480
	Fin. Ben.[e]	449	515	532	536	446	513	530	534	375	446	490	513
	Imports	-	-	-	-	-18	-1	Neg.	Neg.	-44	-18	-6	-1
	Exports	-	-	-	-	283	282	282	282	286	283	282	282
	Δ Farm Inc.	-316	-333	-335	-335	32	32	32	32	32	32	32	32
(B)	Fin. Ben.[b]	234	247	248	248	254	268	269	269	234	254	264	268
	Fin. Ben.[c]	314	330	331	331	313	329	331	331	290	313	325	329
	Fin. Ben.[d]	227	240	241	241	227	240	241	241	209	227	236	240
	Fin. Ben.[e]	234	247	248	248	234	246	247	247	215	234	243	246
	Imports	-	-	-	-	-1	Neg.	Neg.	Neg.	-6	-6	Neg.	Neg.
	Exports	-	-	-	-	85	85	85	85	85	85	85	85
	Δ Farm Inc.	-112	-113	-113	-113	-2	-2	-2	-2	-2	-2	-2	-2
(C)	Fin. Ben.[b]	85	86	86	86	91	92	92	92	87	91	92	92
	Fin. Ben.[c]	110	111	111	111	110	111	111	111	106	110	111	111
	Fin. Ben.[d]	84	85	85	85	84	85	85	85	80	84	85	85
	Fin. Ben.[e]	85	86	86	86	85	86	86	86	82	85	86	86
	Imports	-	-	-	-	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
	Exports	-	-	-	-	19	19	19	19	19	19	19	19
	Δ Farm Inc.	-25	-25	-25	-25	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
(D)	Fin. Ben.[b]	19	19	19	19	21	21	21	21	20	21	21	21
	Fin. Ben.[c]	25	25	25	25	25	25	25	25	25	25	25	25
	Fin. Ben.[d]	19	19	19	19	19	19	19	19	19	19	19	19
	Fin. Ben.[e]	19	19	19	19	19	19	19	19	19	19	19	19

[a] Storage rules aimed at limiting price fluctuations at 2, 3, 4, and 5 percent of the desired mean price $\bar{P}$=Rs. 850 per ton are denoted by (A), (B), (C), and (D), respectively. For standard deviations of the estimates, see Appendix Table D2.

[b] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[e] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Scheme A is followed, the relatively large stock-on-hand over the entire period provides more cushion to check a rise than a fall in prices. Farmers lose because, in the absence of export avenues and the limitation on storage capacity, the fall in prices in the face of good harvest could not, for all the years, be arrested by syphoning out the surpluses above the stability requirement. Obviously, the larger the initial investment, the greater would be the loss to the farmers. When Scheme B or C is followed, farmers gain the same amount even if the size of the storage program is increased because the excess supplies above the storage requirement are always assured of an export outlet.

When a storage program is launched with an initial stock equal to the maximum storage capacity, the total of the withdrawals from the storage over the entire period could not be less than what is put into storage during the period. The present values of financial benefits in stock operation from domestic sources were thus obtained as positive. Sample estimates of the present value of financial benefits under the storage, handling, and transportation charges at the 1971 levels suggested that, of the four cases considered, it would be best to store and sell the grains in the free retail markets at the consuming centers or, as second best, to store and sell in the free wholesale markets at the purchasing centers. Financial return would be less if the grains were sold through the fair price shops in the consuming centers at a fixed price and would decline further if stored and sold in the free wholesale markets of the consuming centers.

Details of the estimated results for lowering or raising the domestic grain purchase prices around the 1971 level are given in Appendices Table D3 to Table D10. One thing is clear from all these results: the sum total of financial involvements (inclusive of initial investment) in the stabilization program is a net loss, which is undoubtedly of a very high order. When viewed with the instability of the estimates as indicated by their standard deviations, this adds a further dimension of risk to storage investment for buffer stock operations. True, the costs and benefits of the buffer stock operations indicated here are approximates and incomplete because the simulation approach is unable to measure many indirect benefits of the stabilization program. Even then, comparing the rate of decline in price and farm income fluctuations and the corresponding rise in the financial cost, the wisdom for a large storage program can be seriously questioned. An ideal approach would be to have a relatively smaller storage plan supported by imports and exports whenever opportunity permits. Political considerations may, however, dictate adoption of a food self-support policy, but then the program no longer remains in the realm of economics.

The results are suggestive and can in no way be taken as final for evaluating the alternative buffer stock programs. For one thing, the estimated results are obtained from storage rules which are not optimum. Moreover, the assumed values of the parameters are dated and open to question.

VI. OPERATIONAL POLICIES FOR FOOD MANAGEMENT WITH GRAIN RESERVES

A buffer stock program has now become an integral part of the overall food and agricultural policy of India. In this concluding chapter, we critically review the operational policies of the government and suggest alternative policies for food management by stocks.

Objectives and Instruments of Government Operations in Food Grains

Over the past several years, what has emerged as the objectives of the government on the food problem can broadly be enumerated as: (a) increasing the level of production, (b) stabilizing relative prices, and (c) protecting the consumption levels of low income groups.

For the attainment of these objectives, the government purchases food grains and makes distributions. There are two sets of prices through which the government can purchase food grains--support prices and procurement prices. Support prices are to provide incentives to the producers and bring stability in price and income to minimum levels. These prices are announced in advance of the sowing season to influence cultivators' production decisions. They are backed by guaranteed government purchase if market prices fall below support levels. Purchases under the price support scheme have practically remained inoperative in India.

To cope with the increasing demand for public distribution, procurement operations have been introduced. Here, the government purchases food grains from the producers, traders and millers, with an element of compulsion, at prices called procurement prices. Until recently, the free market prices have rarely threatened to fall below the procurement prices. With an overall shortage situation prevailing in the country, the latter have generally played the functional role of support prices. The methods of procurement that have been tried so far with varying degrees of success or failure in different parts of the country are: (a) a levy on producer and/or miller, (b) voluntary purchase from millers and wholesalers on an agreed basis as to quantity and/or price, (c) pre-emption on market sales/auctions, and (d) monopoly purchase.

The targets for annual purchases are generally fixed in relation to the requirements for intra-year distributions and for buffer stocks. Intra-year distributions are made to (a) institutions and military, (b) roller flour mills, and (c) fair price shops for direct distribution to consumers. The responsibility to supply to the roller flour mills was taken up during imports under PL 480 agreement when two distribution outlets were used for releasing the imported wheat, viz. the fair price shops and the roller flour mills. Supplies to the mills continue to remain regulated lest their entry in the market might push up the price and frustrate the government's procurement operation. Roller flour mills sell their products to bulk consumers or to state governments for distribution through fair price shops at prices prescribed by the government.

The distribution outlet for the purchased food grains to the consumers is through the fair price shops system. Releases from the buffer stocks are also tied up with this system. Under this scheme, consumers get given quantities of food grains at more or less fixed prices through the fair price shops. The objectives of distribution through fair price shops are to bring down prices in the food grains markets, and thus to protect the low income groups from high prices of food grains. In practice, the system is used to provide a steady supply to urban areas. The rationale is that the flows to the urban areas generally dry up most easily during the period of shortages. Therefore, the urban areas with their high purchasing power and greater vulnerability to price fluctuations are likely to suck away part of the rural demand. Cordoning off the big cities along with the fair price shops system is thus justified for equalizing the distribution between the high income cities and the low income rural areas.

Therefore, the quantity distribution part of the government operations in food grains has three components and buffer stocks are the accumulation of annual purchases minus annual distribution over time. Of the three components of distribution, the supply to the institutions and military and to the roller flour mills are not of major significance to the government's food management operations. They are small, fairly stable, easily measurable, and controllable. The more crucial and difficult to operate is the remaining one, i.e., direct distribution to consumers through fair price shops. Purchase for buffer stock also is a very big task. They are flexible and their dimensions will depend upon the preference function of the policy maker. The distribution to low income groups has an explicit welfare objective. Its operation will require identification and estimation of the low income group and also the minimum level of welfare that the society will be willing to provide to this group. The actual operation of the scheme will ultimately have to rest to a certain degree on arbitrary choices on the part of the policy maker. Given these choices, the volume of distribution under this scheme, however, will be functionally related with the stabilization goals of the buffer stock agency.

Food Grain Requirements for Intra-Year Distribution

Purchases and distribution requirements for buffer stock operation arise only during good and bad years of harvest and such stocks will be built up over time through a clearly stated, inter-year price stabilization objective of the government. However, even in normal years with output just matching the aggregate demand, the government will have to purchase a certain quantity of food grains to fulfill its commitments for intra-year distribution. The quantity of these purchases will evidently depend upon the extent to which the government wishes to involve itself in food grains operation.

We begin the analysis of purchases and commitments when, for equitable distribution, the government takes the responsibility of transferring grains from surplus to deficit areas. Table 24 (derived from Table 7) provides the estimated requirements for distribution for 1986 and 2001 under a number of alternative distribution schemes. If the government takes the entire responsibility of distribution in urban areas and also agrees to balance the rural deficits which may appear in some states, the requirements for the two food crops, rice and wheat alone, increase from 16 million tons in 1971 (average of 1968-71) to 26-28 million tons in 1986 and to 42-46 million tons in 20001. If grains are allowed to move from rural to urban areas of each state and government takes the responsibility of transferring surpluses from the surplus to deficit states, the requirements for the two crops together rise from 9 million tons in 1971 to 14-16 million tons in 1986 and to 21-24 million tons in 2001. The requirements would diminish if the states are grouped into a large zones system since the surplus of some states in the zone would balance the deficit of others within the same zone. Thus, if the country is divided into four large zones as indicated in Table 7, the requirements for rice and wheat together rise from 6 million tons in 1971 to only 8-12 million tons in 1986 and about 13-17 million tons in 2001.

None of the above estimates (derived from the projected state, rural and urban demands) provides the magnitude of the requirement if the distribution program has to ensure a minimum supply to the consumers based on certain nutritional norms. Recently, a number of studies have made an attempt to estimate what this magnitude might be. Although these

Table 24. Requirements for intra-year distribution under alternative schemes (million tons)

	1971 Average of 1968-71	1986 High Projection	1986 Low Projection	2001 High Projection	2001 Low Projection
A. If the distribution is made to cover the entire urban demand plus the excesses of rural demands which may arise in the states					
1. Rice	6.27	17.43	17.49	30.46	28.86
2. Wheat	10.33	9.03	9.82	15.35	15.22
3. Rice and wheat	16.60	26.46	27.31	45.81	42.08
4. Cereals	16.34	31.11	36.20	53.73	54.56
5. Food grains	19.16	34.90	39.91	59.88	60.45
B. If the distribution is made to cover only the total urban demand					
1. Rice	2.70	10.85	9.84	18.61	13.27
2. Wheat	6.71	3.23	5.75	5.24	8.42
3. Rice and wheat	9.41	14.08	15.59	23.85	21.69
4. Cereals	8.52	17.89	23.61	30.62	33.75
5. Food grains	10.82	20.15	25.32	33.77	35.24
C. If the states are grouped in large zones and the distribution is made to meet the zonal deficits					
1. Rice	0.45	5.36	6.49	8.88	9.10
2. Wheat	6.17	3.18	5.33	4.78	8.04
3. Rice and wheat	6.62	8.54	11.82	13.66	17.14
4. Cereals	6.00	10.04	22.52	15.85	32.35
5. Food grains	7.24	11.02	23.03	16.64	32.62

studies provide widely varying estimates, even the most conservative one places the requirement for intra-year distribution at a level which would require not only nationalization of food grains trade but also control over farm consumption. Thus, the National Commission on Agriculture (Government of India, 1975) estimated a 12 million ton distribution program for 1975 which, in essence, caters to the needs of all people in the cities above one lakh population, irrespective of whether they are rich or poor. Other studies were more ambitious. Gulati and Krishnan (1975) estimated for 1973, a 25 million ton distribution program to cover both the urban and noncultivating rural population; Byas and Bandopadhyaya (1975) suggested a scheme which would have required anywhere between 33 and 53 million tons of food grains for distributing in 1974-75.

Past records provide an idea of the task involved in food management operations if the intra-year distribution has to proceed along certain nutritional norms. In the absence of imports, if any of the above estimates is accepted, the government would have to carry out procurement at a level which could range from a minimum of 15 percent to as high as 60 percent of the annual production, far exceeding the available normal marketable surplus in the country. The fact of the case is that even at the peak of its operation, government purchases have not been able to cross the 10 million tons mark. In the past, the government was able to maintain annual food grains distribution at a higher level than the corresponding purchases (procurement) because of the availability of imported grains; but in no year, save the crisis period of 1965-68, did it cross 10 percent of the total consumption (Table 25). In fact, during the period

Table 25. Public distribution of cereals[a]

	Output (mil. tons)	Percent of output procured	Total consumption (mil. tons)	Import content in total consumption (percent)	Percent of total consumption issued by the government		Price Index (1952-53=100)
					Total	Through Fair Price and Ration Shops	
1957	60.31	0.49	55.54	6.53	5.49	4.38	102
1958	56.52	0.93	52.94	6.07	7.52	6.23	105
1959	65.59	2.75	60.75	6.35	8.50	6.54	104
1960	65.25	1.95	60.82	8.43	8.12	7.49	105
1961	69.59	0.78	64.55	5.41	6.16	3.88	102
1962	70.69	0.68	65.84	5.53	6.63	4.01	106
1963	68.79	1.09	64.76	7.03	8.00	5.11	112
1964	70.62	2.02	69.29	9.04	12.50	9.41	134
1965	76.95	5.24	73.72	10.10	13.67	11.51	145
1966	62.40	6.42	64.80	15.95	21.74	18.60	165
1967	65.88	6.77	66.57	13.02	19.78	17.38	207
1968	82.95	8.20	76.23	7.46	13.41	11.15	205
1969	83.60	7.63	76.53	5.02	12.26	9.61	204
1970	87.81	7.65	79.30	4.51	11.55	8.36	208

[a]Source: Government of India, 1969a.

1957-62 when market prices were stable, the gaps between the market and the fair price shop issue prices were kept too wide. The public distribution system was provided with ample stocks and a large part of them were not procured or replenished from the domestic market but were obtained as net additional supplies from abroad. The withdrawal from the fair price shops during the period 1957-62 did not exceed 8 percent of the total consumption. Under this favorable situation, the consumers who were then drawing grains from the public distribution system were likely the needy poor who could not afford to purchase grains from the free market. These withdrawals might not have fully meet the nutritional requirements of the low income group of the population. But to provide the full requirement entirely from the public distribution system, it would have become necessary to fix the issue prices at further lower levels. And we show presently the coexistence of a public distribution and free market systems does not allow arbitrarily fixing the issue prices in the public distribution system at higher or lower levels than rule in the free market.

Interrelationship of Government Operations with the Free Market

Whatever the dimension of government purchases and distribution, the operational policies for them should be feasible to implement and should produce the desired results. At present, government food grains operations are conducted with a set of instruments which are rigid in the sense that they are fixed before each operation and cannot be altered to adjust with changing market situations. Government commits itself to distribute a certain quantity at a certain fixed price and, directly or indirectly coerces the producers and traders to supply the required quantity at a certain prescribed price. The system can work only if economic criteria are used in fixing the levels of each of the above variables. So far, the practice has been somewhat different with obviously frustrating outcomes.

The public distribution system is perceived by government as an instrument through which it can simultaneously operate to (a) influence the market prices, (b) maintain a steady supply to urban areas, and (c) induce a change in the income distribution. These elements are envisaged as resulting from the establishment of a separate market of fair distribution. Here the government-determined supply has to come from the partial procurement of the total supply at a price lower than the free market with procurement then distributed to consumers as a part of their total requirements, again at a price lower than the free market.

The viability of this system of public distribution, however, rests basically upon the levels at which government-determined prices are fixed since the forces of demand and supply in the two markets are inter-linked through their relative price structure. Quantity demanded from the public distribution system is functionally related to the difference between the price in the fair price shops and the free market price. The wider this difference is, the greater will be the demand. Also, compared to the free market, the public distribution system is less preferred for reasons that the Study Team on Fair Price Shops has observed as "consumers preferences for qualities of grains and relative conveniences of the two systems of distribution (Government of India, 1966b)." Because of this, the Team has argued that the public distribution system can influence the free market price only when releases from it act as net additions to the total market supply. This could be obtained by lowering or raising the prices in the fair price shops, but in either case, the impact on the free market price would be of small order compared to the corresponding price adjustment made in the fair price shops.

The system collapses if it is run on the basis of a partial withdrawal of the total supply for distribution at a lower than market price. It cannot then bring down the price in the residual market. Under such a situation, public distribution systems can function alongside a free market only if the price in the fair price shops is made market-oriented as illustrated in Figure 2.

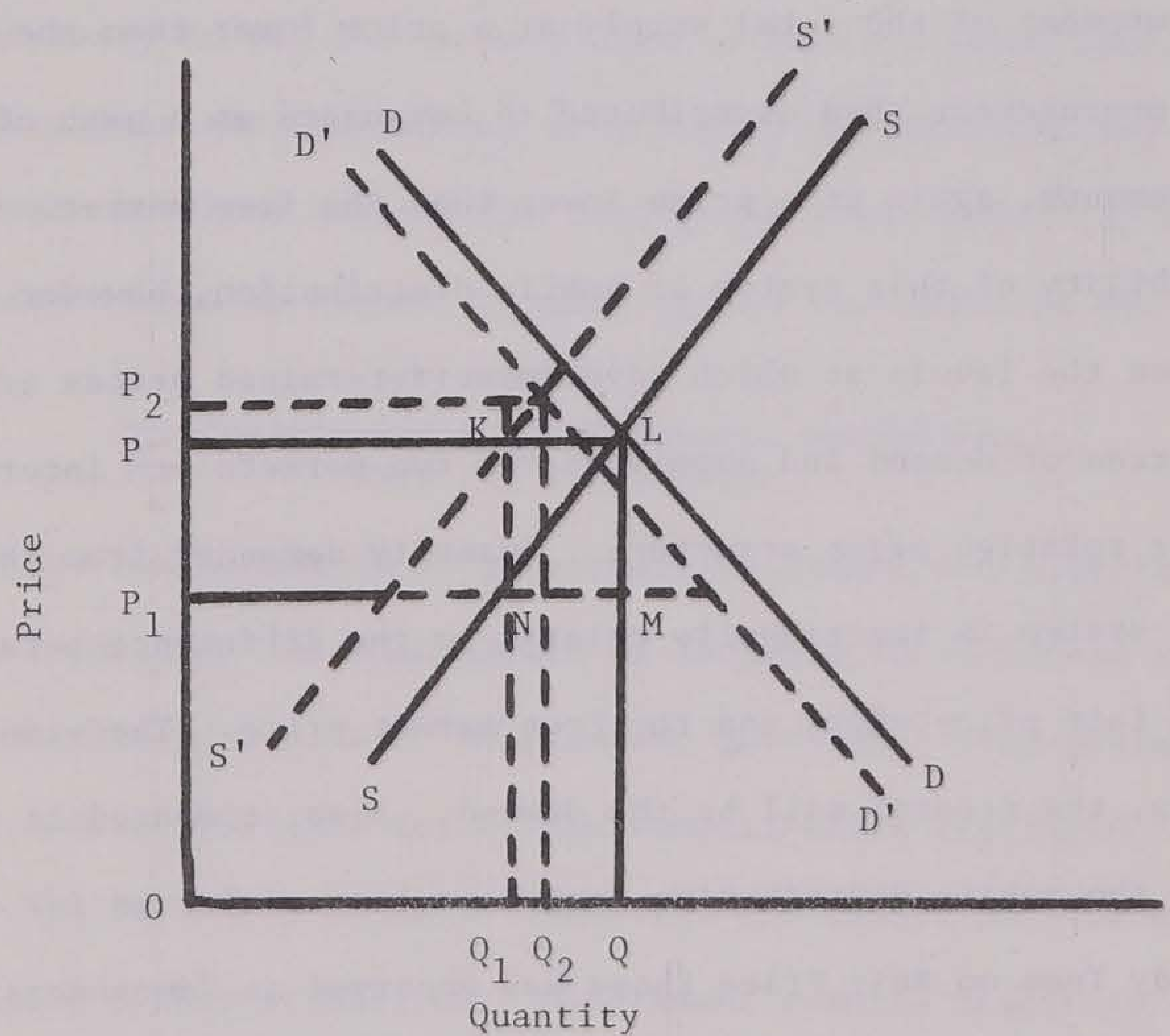

Figure 2. Effect of public distribution system on a free market

With the market demand curve DD, for a given level of output, let the supply curve be SS so that a quantity OQ is cleared at a price OP. Suppose, the government considers this price to be too high and, in order to provide relief to the consumers, procures a quantity Q_1Q for distribution at a price lower than OP, say at OP_1. Both the free market demand and supply curves will then shift to the left but the extent of the shift in the former is likely to be less than in the latter. This may happen because of the relative convenience of the two systems of distribution mentioned earlier. Also, since part of the total supply is now made available at a lower price, an excess demand situation will develop and consumer demand will get augmented. The residual market will then fix the price at OP_2 and clear a quantity OQ_2. Total supply now (i.e., OQ_2 plus Q_1Q) will be more than what it would have been in the absence of government operation, but the market price and the difference between it and the distribution price also will now be higher than previous levels. As a result, pressures will build up on the public distribution system and after making distribution of the procured quantity, it will discover that it is in a precarious position to meet this additional demand. The only alternative then will be to ask consumers to satisfy their additional demand from the residual market. This should increase total consumption and also raise the price. Those who can pay more will now be consuming more.

In Figure 2, both the market demand and supply curves are allowed to make a parallel shift. Also, the shift in the supply curve is shown equal to the quantity procured by the government. Neither of these is likely to hold true in actual situation; they will be governed by the government's operational policies regarding food grains procurement and distribution. The magnitude of the shift in demand has a direct relationship with the quantity distributed; it also has an inverse relationship with the difference between the free market price and the distribution price. The wider the price differential or lower the quantity distributed the lesser will be the shift of the demand curve toward the left. The shape of the demand curve can also be influenced by adopting a discriminating price policy for distribution. For instance, suppose the government makes distribution of the procured quantity Q_1Q at two prices -- a low price, say OP_1 for the low income group, and a high price, say around OP, for the high income group. A section of the high income group will then withdraw from the public distribution system and may as well substitute food grains by other food items of greater utility. At the same time, the released pressure of the high income group will provide an opportunity to the public distribution system to meet more adequately the needs of the low income group. The consequences of all these is likely to make the demand curve DD' more elastic and may shift it more towards the left.

When the government procures the quantity Q_1Q at a low price, say at OP_1, the suppliers' revenue declines by an amount $P_1P \times Q_1Q$ (KLMN). There will thus be an anxiety on the part of the suppliers to sell the residual quantity in the free market at a price at which they could at least recover the loss. If this is not forthcoming through the forces of the new market demand curve, suppliers will try to evade procurement and, thereby, create ideal conditions leading to speculative demand for inventories from traders and consumers alike. Once these unhealthy activities develop, the supply curve S'S' becomes more inelastic and food management begins to become increasingly unmanageable. A vicious circle is created in food management with spiralling consequences. High market prices increase the pressure on the public distribution system and compels the government to have a more ambitious procurement plan. An ambitious plan, in turn, stretches the procurement net beyond the manageable limits of the government. Tendency to evade procurement can cause a further rise in speculative demand and market price. This outcome has been commonly experienced in the past, particularly during the years of crises.

To make the procurement operation a success, the government has often adopted measures which are attempts to defy the principle of market mechanism. One of these is the much debated policy of movement restrictions (Krishna, 1965a; Khusro, 1967; Cochrane, 1968; Ray, 1970) which continues to remain a part of the government operations in food grains. The government has justified movement restrictions on the ground that its procurement efforts for equitable distribution of food grains in the prevailing shortage situation would be frustrated if the profit motivated private traders were allowed to operate freely.[1] However, an analysis of the dezoned and zoned periods market prices of 1961-63 and 1966-68 indicated that food zones actually accentuated regional price differences (Ray, 1970). Prices were depressed in surplus states but there was a sharp increase of prices in deficit states.[2]

An extreme form of market intervention was mooted in 1972-73 when the government nationalized wholesale trade in wheat and rice. The objective behind the move was to ensure a more regular flow of supplies to consumers at reasonable prices through the fair price shops. The experiment, however, was carried out only on wheat in 1972-73. It failed and was subsequently given up.

The move for nationalization of wholesale trade in food grains was conceived wrongly on the assumption that the entire marketable

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[1]Cochrane (1968) listed four government arguments in favor of food zones. These are (a) a political and administrative argument, (b) a physical concept of procurement, (c) a big-city excess purchasing power argument, and (d) a cost argument. Cochrane has made critical comments on all these arguments except the first which in his opinion was "at the heart of the whole matter, and, in a political sense a valid argument". Commenting against zones, Krishna (1965a) observed, "...when Governments determine transfers, the quantities to be taken out of surplus states, the quantities demanded by deficit states, and the quantities allocated by the Center-all these become political rather than economic quantities. Transfers so determined can hardly be expected to minimize price disparities".

[2]Khusro (1967) gave four economic arguments against zones. These are: (a) by keeping producer prices in surplus areas lower than they would otherwise be, zones depress production in surplus areas where precisely it ought to be encouraged for reasons of better endowment; (b) by keeping consumer prices in surplus areas lower than they would otherwise be, zones encourage consumption in these areas; (c) by keeping consumer prices in deficit regions higher than they would be, zones depress consumption in these regions, hit the consumers here harder than is necessary and make for national disharmony; and (d) by keeping producer prices in deficit areas higher than they would be, zones perpetuate production in regions badly endowed and tie up resources precisely where these should not be tied up.

surplus could be procured only if the traders were eliminated. It failed because "the rich farmer who has considerably improved his marketable surplus as well as retaining capacity ... has been left free to manipulate his stocks as he likes" (Rao, 1974). Besides this experience of failure, the take-over move raises a number of serious questions (Subbarao, 1973), the most important of which arises from its implications on resource allocation. Nationalization of food grains trade may divert resources from food to nonfood crops, and in the long run may adversely affect the levels of food grains production which, in the final analysis, is at the root of India's food problem.

Operational Policies for Food Management

The built-in inconsistencies in the present system of food management operations bring in sharp focus the conflicting goals and policies of the government on the food front. Government desires to protect the interests of the low income group and for this reason, to withdraw a part of the total domestic supply for distribution at a low price. If this plan is executed, government loses control over the free market and the objective of influencing the market price is defeated. The market price can be influenced only by following a market-oriented price policy for distribution. But if it is adopted, the objective of protecting the interests of the low income group gets defeated. Government wants to minimize the cost of distribution through procurement of the required quantity at a low price, but when this is attempted through various control measures, market imperfections result and adversely affect the objective of increasing the level of production.

Actions, too, contradict the intentions. The government intends to provide incentives to the producers but adopts measures that directly or indirectly take away the production incentives. To regulate the in-flow of food from the rural poor to the urban rich, government takes the responsibility of distribution in urban areas. Yet, distribution proceeds not in relation with the purchasing capacity of the individual consumers but at a uniform low price for which the society pays a subsidy.

In India, government involvement in food management operations has sprouted from the moral dictates of a society which is characterized by recurring food shortages and extreme inequality in the distribution of income. These conditions have had a long history and compulsion is likely to remain so long as the shortages are felt and wide disparities in income continue. The solution to India's food management problem rests basically on raising the level of food grains production and supplies and making income distribution less skewed. Until these conditions are reached, the government must operate and protect the larger interests of society. It must purchase food grains and make distribution, not only for providing a steady and assured supply to the organized and politically sensitive urban communities, but also to provide distributive justice so that the poor as well as the rich have opportunity for subsistence.

Equitable distribution, in the India context of food shortages and income inequalities, is possible only by making the distribution income neutral. The level of consumption should be so influenced that each consumer consumes the same quantity irrespective of his level of income. If society decides to provide the same amount of food to all sections of the community and, at the same time, does not want to abolish the free market, an equitable distribution can be obtained only by penalizing those who can afford to consume more. In a free society, this is possible by deliberately following a discriminating policy of distribution in which the rich are penalized with a high price and the poor are compensated with low price.

The fact of the case justifies the suggestion. Public distribution of food grains in India is highly urban oriented. But, the logic for distribution to all sections of the urban community at a uniformly low price is not clear. If the justification for the entire coverage of the urban areas under public distribution system lies in the valid concern of an excess purchasing power capacity of the urban community, the appropriate policy should be to ensure the certainty of supply to urban areas at a price that reflects the market conditions, and not guaranteed supply at a subsidized price. If the urban areas are also the concentration pockets of low income groups, then their presence should be recognized explicitly and distribution should proceed by separately charging the low income groups a low price.

Certain ills in the present system of food management operations originated from the government's misplaced concern for fair distribution to all sections of the community at a uniformly subsidized price. Fair distribution has been conceived as distribution at a reasonable price. But reasonableness has been viewed only in relation to the unweighted interests of all consumers. Consequently, the concept has led to the notion of reasonable price as a consumer-oriented unchanging price which is fixed through subsidy at a level below market prices.

Since the government has to make distribution at a subsidized price, so runs the argument, the government should procure the required quantity for distribution at a price lower than the market and thus realize part of the subsidy from the producers and traders. This need not and should not be the strategy in food management for two reasons. First, a public distribution system is now viewed exclusively as an instrument for catering to the needs of low income people. It is now functioning primarily to ensure the certainty of supply in urban areas where the majority of people are employed in organized industries and enjoy pay revisions according to changes in the cost of living. On the other hand, the rural sector is crowded with a large number of unemployed and underemployed and suffers most from rising prices. Moreover, rural income is highly correlated with production. An urban-oriented, subsidized distribution program thus goes against the declared public policy of ensuring equitable distribution at reasonable prices to all sections of the people. Second, and more important, is the concern for the viability of the food management system. As mentioned earlier, the coexistence of a public distribution system with a free market is possible only by adopting a market oriented distribution policy. Subsidized distribution will make the system vulnerable to the pressures of free market.

To the extent the distribution is made to the low income group, the need for subsidized distribution cannot be ignored. A careful identification and estimation of the low income population is, however, essential. Obviously, it cannot include the entire urban community. The prevailing socioeconomic conditions should be weighed carefully to decide who qualifies as a low income family and what measure of relief should be provided. Distribution can then be made at two prices: a stable subsidized price for the low income group and a price, reflecting more accurately the market conditions, for others.

Rather than the concern for a subsidized distribution to all, the government's strategy in food management could be to acquire command over a larger and larger share of the total distribution system. But, the government can acquire this position of strength only by aiming at maximizing the quantities of grains it handles at appropriate prices. Theoretically, the government can make distribution of the entire marketable surplus by purchasing the grains at market prices. This, of course, would enable the government to undertake a large distribution program with certainty of supply. However, the presence of a large body as the government in the market with the intention of purchasing the entire marketable surplus at market prices obviously would be exploited by the producers and traders. Prices will be pushed up, thereby compelling the government to subsidize distribution.

Corrective measures to check violations of market disciplines can be maintained partly through buffer stock operations. Once a buffer stock agency (after a careful assessment of the demand and supply conditions) realistically fixes the price bands, its stock operation for containing the price within the desired limits is likely to have a sobering impact on the market forces. At the same time, a penalty should be imposed on those who attempt to cross the price bands with a mechanism which can work compatibly with the private market. This can be in the form of a preemptive purchase scheme, used in Punjab during 1958-59. Under this scheme, the government reserves the right to procure varying proportions of each day's total market arrivals. At the end of the day, however, government purchases all or part of that proportion only if the price is favorable. The scheme penalizes both the shy as well as the aggressive bidders and at the same time helps the buffer stock agency to fix the price bands at appropriate levels. An increasing tendency of deviations registered in the market will signal the buffer stock agency to adjust the price bands at levels reflecting more accurately the market conditions.

Partial distribution at two prices combined with buffer stock operation and open market purchases with preemptive rights carry the promises for a viable food management system. The distribution to the low income group and the consequent question of sharing the burden of subsidy, however, still remains. The subsidy cannot be compensated through other consumers by charging a high price because a distribution price fixed above the market level will introduce instability in the system. The other possibility is to realize the subsidy from the producers and this can be in the form of procurement at lower than market prices. To the extent the subsidized distribution is made to the low income people, procurement of the required quantity at a lower price can be justified but then, for effective redistribution of income, the strategy for procurement should be such that the burden of the subsidy falls increasingly on the rich farmers. In fact, procuring only from the rich and distributing only to the poor at lower than market prices has "the merit of redistributing income from the rich farmers and the rich consumers, on the one hand, to small farmers and the poorer consumers, on the other" (Rao, 1974). It can, however, dampen supply response as it helps the real price of grains to be maintained at a lower level.

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APPENDIX A

Table A1. Projected rural and urban population as on April[a] (million)

	1956-59 (average)[b]			1971			1986			2001		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
North												
Jammu & Kashmir	2.84	0.55	3.39	3.76	0.86	4.62	4.92	1.58	6.50	5.97	2.38	8.35
Punjab & Haryana[c]	14.84	7.04	21.88	22.26	9.11	31.37	28.74	15.00	43.74	34.59	23.20	57.79
Rajasthan	15.20	3.04	18.24	21.22	4.55	25.77	27.58	7.45	35.03	33.32	11.37	44.69
Uttar Pradesh	59.60	8.79	68.39	75.95	12.39	88.34	91.99	18.44	110.43	106.47	27.12	133.59
Total	92.48	19.42	111.90	123.19	26.91	150.10	153.23	42.47	195.70	180.35	64.07	244.42
East												
Assam[d]	11.92	1.04	12.96	17.82	1.88	19.70	24.55	2.17	26.72	30.63	6.93	37.56
Bihar	39.27	3.63	42.90	50.72	5.63	56.35	62.05	9.64	71.69	72.29	15.14	87.43
Orissa	15.19	1.03	16.22	20.10	1.84	21.94	25.30	1.92	27.22	29.93	6.52	36.45
West Bengal	22.53	8.92	31.45	33.34	10.97	44.31	43.54	16.03	59.57	52.76	23.06	75.82
Total	88.91	14.62	103.53	121.98	20.32	142.30	155.44	29.76	185.20	185.61	51.65	237.26
West												
Gujarat[e]	14.36	5.02	19.38	19.91	7.72	27.63	25.74	13.03	38.77	31.02	20.41	51.43
Madhya Pradesh	25.27	4.29	29.56	34.88	6.78	41.66	45.31	11.89	57.20	54.74	18.97	73.71
Maharashtra	24.76	11.35	36.11	34.70	15.71	50.41	43.66	26.00	69.66	51.76	40.52	92.28
Total	64.39	20.66	85.05	89.49	30.21	119.70	114.71	50.92	165.63	137.52	79.90	217.42
South												
Andhra Pradesh	27.85	5.82	33.67	35.10	8.40	43.50	42.50	13.04	55.54	49.18	19.45	68.63
Kerala[f]	13.09	2.37	15.46	17.91	3.47	21.38	23.04	5.53	28.57	27.66	8.25	35.91
Mysore	16.84	4.88	21.72	22.18	7.12	29.30	27.61	11.20	38.81	32.51	16.80	49.31
Tamilnadu[g]	22.75	9.42	32.17	29.01	12.66	41.67	34.45	20.60	55.05	39.36	31.99	71.35
Total	80.53	22.49	103.02	104.20	31.65	135.85	127.60	50.37	177.97	148.71	76.49	225.20
All-India	326.31	77.19	403.50	438.86	109.09	547.95	550.98	173.52	724.50	652.19	272.11	924.30

[a]Projected populations of the Union Territories are included in the states with which they are geographically contiguous.

[b]1956-59 average urban population is first estimated at the all-India level from the growth rate obtained during 1951-61. It is distributed over the states according to the proportions obtained in the 1961 Census. The rural population figure is obtained by subtracting the states estimated urban population from the corresponding total.

[c]Includes Himachal Pradesh, Delhi and Chandigarh.

[d]Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[e]Includes Goa, Daman, Diu, Dadra and Hagar Haveli.

[f]Includes Arabian Islands.

[g]Includes Pondicherry.

Table A2. State aggregate demand for food grains for human consumption (million tons)

	1971		1986				2001			
			High Projection		Low Projection		High Projection		Low Projection	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
North										
Jammu & Kashmir	0.84	0.15	1.18	0.28	1.13	0.28	1.74	0.48	1.50	0.43
Punjab & Haryana[a]	3.94	1.30	5.96	2.39	5.59	2.32	9.23	4.28	7.58	3.85
Rajasthan	4.13	0.75	6.06	1.29	5.74	1.25	9.16	2.21	7.64	1.99
Uttar Pradesh	13.83	1.93	18.72	3.05	17.88	2.97	26.64	5.08	22.69	4.61
Total	22.74	4.13	31.92	7.01	30.34	6.82	46.77	12.05	39.41	10.88
East										
Assam[b]	3.77	0.34	5.78	0.40	5.45	0.39	9.02	1.41	7.47	1.25
Bihar	9.84	0.96	13.30	1.70	12.71	1.65	18.89	2.98	16.11	2.68
Orissa	3.27	0.29	4.84	0.31	4.58	0.30	7.35	1.28	6.13	1.13
West Bengal	6.93	1.98	10.07	2.92	9.52	2.86	15.14	4.54	12.61	4.18
Total	23.81	3.57	33.99	5.33	32.26	5.20	50.40	10.21	42.32	9.24
West										
Gujarat[c]	3.22	1.10	4.98	2.08	4.69	2.01	7.84	3.80	6.42	3.40
Madhya Pradesh	6.08	1.06	9.24	2.00	8.72	1.94	14.29	3.65	11.79	3.27
Maharashtra	5.54	2.17	8.32	4.06	7.83	3.93	12.82	7.42	10.52	6.66
Total	14.84	4.33	22.54	8.14	21.24	7.88	34.95	14.87	28.73	13.33
South										
Andhra Pradesh	5.94	1.32	8.19	2.18	7.81	2.11	11.82	3.68	10.04	3.32
Kerala[d]	2.60	0.47	4.15	0.86	3.89	0.83	6.64	1.50	5.44	1.34
Mysore	3.64	1.04	5.29	1.79	5.01	1.74	7.96	3.11	6.66	2.79
Tamilnadu[e]	4.63	1.87	6.32	3.32	6.01	3.24	9.07	5.95	7.69	5.36
Total	16.81	4.70	23.95	8.15	22.72	7.92	35.49	14.24	29.83	12.81
All-India	78.20	16.73	112.40	28.63	106.56	27.82	167.61	51.37	140.29	46.26

[a] Includes Himanchal Pradesh, Delhi and Chandigarh.

[b] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c] Includes Goa, Daman, Diu, Dadra, and Nagar Haveli.

[d] Includes Arabian Islands.

[e] Includes Pondicherry.

Table A3. Commodity consumption pattern for states in rural and urban areas NSS 17th round preference period: September 1961 to July 1962 (percentage to food grains consumed)

	Rural					Urban				
	Rice	Wheat	Coarse Cereals	Pulses	All Food Grains	Rice	Wheat	Coarse Cereals	Pulses	All Food Grains
North										
Jammu & Kashmir	55.52	13.98	26.17	4.33	100.00	75.96	17.07	3.86	3.11	100.00
Punjab & Haryana[a]	9.91	53.58	24.87	11.64	100.00	5.20	73.80	7.18	13.82	100.00
Rajasthan	1.63	15.71	73.10	9.56	100.00	3.21	52.20	30.62	13.97	100.00
Uttar Pradesh	24.53	24.82	34.01	16.64	100.00	17.08	52.91	12.32	17.69	100.00
East										
Assam[b]	92.80	1.76	0.11	5.33	100.00	79.77	10.01	0.07	10.15	100.00
Bihar	58.75	13.54	15.16	12.55	100.00	57.94	27.30	2.38	12.38	100.00
Orissa	88.72	0.33	5.12	5.83	100.00	82.43	7.14	1.47	8.96	100.00
West Bengal	91.63	2.55	0.72	5.10	100.00	72.69	17.54	0.14	9.63	100.00
West										
Gujarat[c]	13.94	13.19	63.38	9.49	100.00	19.44	39.86	27.18	13.52	100.00
Madhya Pradesh	37.48	22.64	28.53	11.35	100.00	21.28	52.02	10.61	16.09	100.00
Maharashtra	21.39	7.64	61.69	9.28	100.00	29.16	24.87	33.23	12.74	100.00
South										
Andhra Pradesh	60.07	0.28	34.48	5.17	100.00	74.31	3.62	12.43	9.64	100.00
Kerala[d]	94.86	0.72	0.19	4.23	100.00	92.00	1.56	0.09	6.35	100.00
Mysore	30.48	2.66	59.35	7.51	100.00	44.62	7.06	36.87	11.45	100.00
Tamilnadu[e]	66.91	0.67	26.71	5.71	100.00	82.78	1.94	6.68	8.60	100.00

[a] Includes Delhi and Himachal Pradesh.

[b] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c] Includes Goa, Daman, Diu, Dadra and Nagar Haveli.

[d] Includes Arabian Islands.

[e] Includes Pondicherry.

Table A4. State aggregate demand for cereals for human consumption (million tons)

	1971		1986 High Projection		1986 Low Projection		2001 High Projection		2001 Low Projection	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
North										
Jammu & Kashmir	0.80	0.14	1.13	0.27	1.08	0.27	1.66	0.46	1.43	0.42
Punjab & Haryana[a]	3.48	1.12	5.27	2.06	4.94	2.00	8.16	3.69	6.70	3.32
Rajasthan	3.74	0.64	5.48	1.11	5.19	1.08	8.28	1.90	6.91	1.71
Uttar Pradesh	11.53	1.59	15.60	2.51	14.90	2.44	22.21	4.18	18.91	3.79
Total	19.55	3.49	27.48	5.95	26.11	5.79	40.31	10.23	33.95	9.24
East										
Assam[b]	3.57	0.30	5.47	0.36	5.16	0.35	8.54	1.27	7.07	1.12
Bihar	8.60	0.84	11.63	1.49	11.11	1.44	16.52	2.61	14.09	2.35
Orissa	3.08	0.26	4.56	0.28	4.31	0.27	6.92	1.16	5.77	1.03
West Bengal	6.58	1.79	9.56	2.64	9.03	2.58	14.37	4.10	11.97	3.78
Total	21.83	3.19	31.22	4.77	29.61	4.64	46.35	9.14	38.90	8.28
West										
Gujarat[c]	2.91	0.95	4.51	1.80	4.24	1.74	7.10	3.29	5.81	2.94
Madhya Pradesh	5.39	0.89	8.19	1.74	7.73	1.69	12.67	3.19	10.45	2.85
Maharashtra	5.02	1.89	7.55	3.54	7.10	3.43	11.63	6.47	9.54	5.81
Total	13.32	3.73	20.25	7.08	19.07	6.86	31.40	12.95	25.80	11.60
South										
Andhra Pradesh	5.63	1.19	7.77	1.97	7.41	1.91	11.21	3.42	9.52	3.00
Kerala[d]	2.49	0.44	3.97	0.80	3.72	0.78	6.36	1.40	5.21	1.25
Mysore	3.37	0.92	4.89	1.58	4.63	1.54	7.36	2.75	6.16	2.47
Tamilnadu[e]	4.36	1.71	5.96	3.03	5.67	2.96	8.55	5.44	7.25	4.90
Total	15.85	4.26	22.59	7.38	21.43	7.19	33.48	12.91	28.14	11.62
All-India	70.55	14.67	101.54	25.18	96.22	24.48	151.54	45.23	126.79	40.74

[a]Includes Himanchal Pradesh, Delhi and Chandigarh.

[b]Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c]Includes Goa, Daman, Diu, Dadra, and Nagar Haveli.

[d]Includes Arabian Islands.

[e]Includes Pondicherry.

Table A5. State aggregate demand for rice for human consumption (million tons)

	1971		1986				2001			
			High Projection		Low Projection		High Projection		Low Projection	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
North										
Jammu & Kashmir	0.47	0.11	0.66	0.21	0.63	0.21	0.97	0.36	0.83	0.33
Punjab & Haryana[a]	0.39	0.07	0.59	0.12	0.55	0.12	0.92	0.22	0.75	0.20
Rajasthan	0.07	0.02	0.10	0.04	0.09	0.04	0.15	0.07	0.12	0.06
Uttar Pradesh	3.39	0.33	4.59	0.52	4.39	0.51	6.54	0.87	5.57	0.79
Total	4.32	0.53	5.94	0.89	5.66	0.88	8.58	1.52	7.27	1.38
East										
Assam[b]	3.50	0.27	5.36	0.32	5.06	0.31	8.37	1.12	6.93	1.00
Bihar	5.78	0.56	7.82	0.98	7.47	0.96	11.10	1.73	9.46	1.55
Orissa	2.90	0.24	4.29	0.26	4.06	0.25	6.52	1.06	5.44	0.93
West Bengal	6.35	1.44	9.23	2.12	8.72	2.08	13.87	3.30	11.56	3.04
Total	18.53	2.51	26.70	3.68	25.31	3.60	39.86	7.21	33.39	6.52
West										
Gujarat[c]	0.45	0.21	0.70	0.40	0.65	0.39	1.09	0.74	0.90	0.66
Madhya Pradesh	2.28	0.23	3.46	0.43	3.27	0.41	5.36	0.78	4.42	0.70
Maharashtra	1.18	0.63	1.78	1.18	1.68	1.15	2.74	2.16	2.25	1.94
Total	3.91	1.07	5.94	2.01	5.60	1.95	9.19	3.68	7.57	3.30
South										
Andhra Pradesh	3.57	0.98	4.92	1.62	4.69	1.57	7.10	2.74	6.03	2.47
Kerala[d]	2.47	0.43	3.94	0.79	3.69	0.76	6.30	1.38	5.16	1.23
Mysore	1.11	0.46	1.61	0.80	1.53	0.78	2.43	1.39	2.03	1.24
Tamilnadu[e]	3.10	1.55	4.23	2.75	4.02	2.68	6.07	4.92	5.14	4.44
Total	10.25	3.42	14.70	5.96	13.93	5.79	21.90	10.43	18.36	9.38
All-India	37.01	7.53	53.28	12.54	50.50	12.22	79.53	22.84	66.59	20.58

[a] Includes Himanchal Pradesh, Delhi and Chandigarh.

[b] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c] Includes Goa, Daman, Diu, Dadra, and Nagar Haveli.

[d] Includes Arabian Islands.

[e] Includes Pondicherry.

Table A6. State aggregate demand for wheat for human consumption (million tons)

	1971		1986				2001			
			High Projection		Low Projection		High Projection		Low Projection	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
North										
Jammu & Kashmir	0.12	0.03	0.16	0.05	0.16	0.05	0.24	0.08	0.21	0.07
Punjab & Haryana[a]	2.11	0.96	3.19	1.76	3.00	1.71	4.94	3.16	4.06	2.84
Rajasthan	0.65	0.39	0.95	0.67	0.90	0.65	1.44	1.15	1.20	1.04
Uttar Pradesh	3.43	1.02	4.65	1.61	4.44	1.57	6.61	2.69	5.63	2.44
Total	6.31	2.40	8.95	4.09	8.50	3.98	13.23	7.08	11.10	6.39
East										
Assam[b]	0.07	0.03	0.10	0.04	0.10	0.04	0.16	0.14	0.13	0.12
Bihar	1.33	0.26	1.80	0.46	1.72	0.45	2.56	0.81	2.18	0.73
Orissa	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.09	0.02	0.08
West Bengal	0.18	0.35	0.26	0.51	0.24	0.50	0.39	0.80	0.32	0.73
Total	1.59	0.66	2.18	1.03	2.08	1.01	3.13	1.84	2.65	1.66
West										
Gujarat[c]	0.42	0.44	0.66	0.83	0.62	0.80	1.03	1.52	0.85	1.36
Madhya Pradesh	1.38	0.55	2.09	1.04	1.97	1.01	3.24	1.90	2.67	1.70
Maharashtra	0.42	0.54	0.64	1.01	0.60	0.98	0.98	1.84	0.80	1.66
Total	2.22	1.53	3.39	2.88	3.19	2.79	5.25	5.26	4.32	4.72
South										
Andhra Pradesh	0.02	0.05	0.02	0.08	0.02	0.08	0.03	0.13	0.03	0.12
Kerala[d]	0.02	0.01	0.03	0.01	0.03	0.01	0.05	0.02	0.04	0.02
Mysore	0.10	0.07	0.14	0.13	0.13	0.12	0.21	0.22	0.18	0.20
Tamilnadu[e]	0.03	0.03	0.04	0.06	0.04	0.06	0.06	0.12	0.05	0.10
Total	0.17	0.16	0.23	0.28	0.22	0.27	0.35	0.49	0.30	0.44
All-India	10.29	4.75	14.75	8.28	13.99	8.05	21.96	14.67	18.37	13.21

[a] Includes Himanchal Pradesh, Delhi and Chandigarh.

[b] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c] Includes Goa, Daman, Diu, Dadra, and Nagar Haveli.

[d] Includes Arabian Islands.

[e] Includes Pondicherry.

Table A7. Present utilization and future potential for irrigation development in India (gross area: thousand acres)

	Major[a]	Minor Surface[b]	Minor Ground[b]	1968-69 Potential Created Major	1964-65 Minor Utilization Surface[b]	1964-65 Minor Utilization Ground[b]	Major[c]	Percent of Potential Utilization Surface[b]	Percent of Potential Utilization Ground[b]	Percentage Distribution of Present Unexploited Irrigation Potential[d]
North										
Jammu & Kashmir	241	1,000	150	151	554	3	63	55.4	2.0	0.58
Punjab & Haryana	10,229	400	6,700	5,773	163	3,603	56	40.7	53.8	6.97
Rajasthan	7,800	1,000	3,500	2,569	474	2,784	33	47.4	79.5	5.53
Uttar Pradesh	18,000	2,500	16,000	7,420	1,401	6,870	39	56.0	42.9	18.48
East										
Assam	2,400	2,500	500	214	1,458	-	9	58.3	-	3.19
Bihar	10,600	4,500	4,050	4,884	2,713	861	46	60.3	19.1	9.14
Orissa	6,000	3,000	1,000	3,068	2,221	171	51	74.0	17.1	3.88
West Bengal	5,700	3,000	2,000	2,729	1,850	38	48	61.7	1.9	5.20
West										
Gujarat	5,300	1,200	3,000	1,309	111	1,629	25	9.3	54.3	5.52
Madhya Pradesh	13,900	2,000	4,000	2,377	309	917	17	15.4	22.9	13.93
Maharashtra	5,800	2,000	3,500	1,578	509	1,882	27	25.4	53.8	6.27
South										
Andhra Pradesh	16,000	5,000	4,500	6,196	2,516	1,218	39	50.3	27.1	13.31
Kerala	1,543	2,000	250	890	549	16	58	27.4	6.4	2.00
Mysore	4,400	2,000	2,000	1,852	890	484	42	44.5	24.2	4.42
Tamilnadu	3,858	2,000	3,250	3,607	1,653	2,002	93	82.6	61.6	1.58
Others[e]		900	150	2,266	655	62	-	72.8	47.3	
Total	112,571	35,000	55,000	46,883	18,026	22,539	42	51.5	41.0	100.00
		90,000			40,565					

[a] Government of India, (1968f).

[b] Government of India, (1968h).

[c] Anticipated potential up to end of 1968-69 from schemes of First Plan and schemes approved during 1966-69 including preplan (Source: Irrigation Division, Planning Commission).

[d] Computed from the previous columns and adjusted for the inclusion of Union Territories within the states, as adopted in this study.

[e] The areas listed as "other" under the columns for "Potential, Minor, Surface", "Potential, Minor, Ground", and "1968-69 Potential Created Major" are all balancing items. These figures were omitted in the cited sources. They should not be considered as accurate data.

Table A8. State estimated production of food grains and cereals (million tons)

	1971		1986				2001			
	Average of 1968-71		High Projection		Low Projection		High Projection		Low Projection	
	Food Grains	Cereals	Food Grains	Cereals	Food Grains	Cereals	Food Grains	Cereals	Food Grains	Cereals
North										
Jammu & Kashmir	1.03	1.00	1.36	1.30	1.82	1.70	1.88	1.77	2.53	2.36
Punjab & Haryana[a]	13.06	11.77	17.03	15.42	30.84	29.57	23.24	21.00	43.03	41.03
Rajasthan	6.65	5.25	9.80	8.14	9.27	7.63	14.73	12.57	12.84	10.59
Uttar Pradesh	18.24	15.16	28.77	24.82	26.86	23.30	45.23	39.61	36.35	32.35
Total	38.98	33.18	56.96	49.58	68.79	62.20	85.08	74.95	94.75	86.33
East										
Assam[b]	2.72	2.67	4.54	4.33	3.70	3.48	7.38	6.89	5.11	4.83
Bihar	8.11	7.09	13.32	11.87	9.58	8.36	21.46	19.18	13.10	11.61
Orissa	4.93	4.49	7.14	6.52	6.02	5.27	10.60	9.63	8.33	7.31
West Bengal	7.74	7.24	10.70	9.96	11.66	10.96	15.33	14.12	16.86	15.21
Total	23.50	21.49	35.70	32.68	30.96	28.07	54.77	49.82	43.40	38.96
West										
Gujarat[c]	4.04	3.88	7.18	6.70	6.94	6.45	12.10	11.12	9.64	8.96
Madhya Pradesh	10.67	8.68	18.62	15.95	12.90	10.45	31.02	27.11	18.10	14.51
Maharashtra	5.82	5.07	9.39	8.35	6.62	5.54	14.98	13.37	9.22	7.69
Total	20.53	17.63	35.19	31.00	26.46	22.44	58.10	51.60	36.96	31.16
South										
Andhra Pradesh	7.08	6.78	14.66	13.73	7.69	7.06	26.52	24.38	10.68	9.80
Kerala[d]	1.31	1.29	2.45	2.33	1.67	1.58	4.23	3.93	2.33	2.19
Mysore	5.97	5.55	8.49	7.86	9.17	8.26	12.42	11.39	12.88	11.46
Tamilnadu[e]	6.83	6.72	7.73	7.54	8.84	8.33	9.14	8.81	12.20	11.56
Total	21.19	20.34	33.33	31.46	27.37	25.23	52.31	48.51	38.09	35.01
All-India	104.20	92.64	161.18	144.82	153.58	137.94	250.26	224.88	213.20	191.46

[a] Includes Himachal Pradesh, Delhi and Chandigarh.

[b] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c] Includes Goa, Daman, Diu, Dadra and Nagar Haveli.

[d] Includes Arabian Islands.

[e] Includes Pondicherry.

Table A9. Estimated production pattern of rice and wheat for states (percentage to state's total cereals production)

	1971		1986				2001			
	Average of 1968-71		High Projection		Low Projection		High Projection		Low Projection	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
North										
Jammu & Kashmir	41.72	19.20	48.48	14.20	55.70	11.58	47.85	14.72	55.78	11.96
Punjab & Haryana[a]	11.01	66.73	12.80	49.38	14.70	40.26	12.63	51.19	14.72	41.57
Rajasthan	2.49	32.55	2.89	24.09	3.34	19.64	2.85	24.97	3.34	20.28
Uttar Pradesh	24.20	47.38	28.12	35.06	32.45	28.59	27.75	36.35	32.49	29.52
Total	16.64	51.02	19.77	37.14	21.08	32.57	19.81	38.09	21.10	33.64
East										
Assam[b]	98.29	0.01	91.22	0.01	96.88	0.01	89.94	0.01	97.01	0.01
Bihar	61.89	18.57	71.91	13.74	82.64	11.20	70.98	14.24	82.75	11.56
Orissa	93.25	0.01	91.87	0.01	97.57	0.01	90.68	0.01	97.71	0.01
West Bengal	87.40	11.13	91.77	8.23	93.29	6.71	90.58	8.53	93.07	6.93
Total	81.56	9.87	84.52	7.53	91.34	5.98	82.96	7.89	91.50	6.16
West										
Gujarat[c]	15.56	20.85	18.07	15.42	20.77	12.58	17.84	15.99	20.80	12.99
Madhya Pradesh	40.55	30.15	47.13	22.31	54.14	18.19	46.52	23.13	54.21	18.78
Maharashtra	29.36	8.85	34.12	6.55	39.20	5.34	33.68	6.79	39.25	5.51
Total	31.83	21.98	37.35	16.58	40.86	13.41	37.00	17.36	40.92	13.83
South										
Andhra Pradesh	67.77	0.04	78.76	0.03	90.47	0.02	77.74	0.03	90.60	0.02
Kerala[d]	99.25	-	99.14	-	99.18	-	98.22	-	99.32	-
Mysore	38.09	2.51	44.25	1.86	51.09	1.51	43.68	1.93	51.16	1.56
Tamilnadu[e]	76.50	0.01	88.90	0.01	93.36	0.01	87.74	0.01	93.49	0.01
Total	64.56	0.69	74.06	0.48	79.11	0.48	79.22	0.47	79.18	0.51
All-India	45.10	24.96	49.94	18.09	49.21	18.71	49.27	18.53	49.27	18.77

[a] Includes Himanchal Pradesh, Delhi and Chandigarh.

[b] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c] Includes Goa, Daman, Diu, Dadra, and Nagar Haveli.

[d] Includes Arabian Islands.

[e] Includes Pondicherry.

Table A10. Estimated production of rice and wheat for states (million tons)

	1971 Average of 1968-71		1986 High Projection		1986 Low Projection		2001 High Projection		2001 Low Projection	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
North										
Jammu & Kashmir	0.42	0.19	0.63	0.18	0.95	0.20	0.85	0.26	1.32	0.28
Punjab & Haryana[a]	1.30	7.85	1.97	7.61	4.35	11.90	2.65	10.75	6.04	17.06
Rajasthan	0.13	1.71	0.24	1.96	0.25	1.50	0.36	3.14	0.35	2.15
Uttar Pradesh	3.67	7.18	6.98	8.70	7.56	6.66	10.99	14.40	10.51	9.55
Total	5.52	16.93	9.82	18.45	13.11	20.26	14.85	28.55	18.22	29.04
East										
Assam[b]	2.62	Neg.	3.95	Neg.	3.37	Neg.	6.20	Neg.	4.69	Neg.
Bihar	4.39	1.32	8.54	1.63	6.91	0.94	13.61	2.73	9.66	1.34
Orissa	4.19	Neg.	5.99	Neg.	5.14	Neg.	8.73	Neg.	7.14	Neg.
West Bengal	6.33	0.80	9.14	0.83	10.22	0.74	12.79	1.20	14.16	1.06
Total	17.53	2.12	27.62	2.46	25.64	1.68	41.33	3.93	35.65	2.40
West										
Gujarat[c]	0.60	0.81	1.21	1.03	1.34	0.81	1.98	1.78	1.86	1.17
Madhya Pradesh	3.52	2.62	7.52	3.56	5.66	1.90	12.61	6.27	7.87	2.72
Maharashtra	1.49	0.45	2.85	0.55	2.17	0.30	4.50	0.91	3.02	0.42
Total	5.61	3.88	11.58	5.14	9.17	3.01	19.09	8.96	12.75	4.31
South										
Andhra Pradesh	4.59	Neg.	10.81	Neg.	6.39	Neg.	18.95	0.01	8.88	Neg.
Kerala[d]	1.28	-	2.31	-	1.57	-	3.86	-	2.17	-
Mysore	2.11	0.14	3.48	0.15	4.22	0.12	4.98	0.22	5.86	0.18
Tamilnadu[e]	5.14	Neg.	6.70	Neg.	7.78	Neg.	7.73	Neg.	10.81	Neg.
Total	13.12	0.14	23.30	0.15	19.96	0.12	35.52	0.23	27.72	0.18
All-India	41.78	23.07	72.32	26.20	67.88	25.07	110.79	41.67	94.34	35.93

[a] Includes Himanchal Pradesh, Delhi and Chandigarh.

[b] Includes Manipur, Tripura, NEFA, Nagaland and Bay Islands.

[c] Includes Goa, Daman, Diu, Dadra, and Nagar Haveli.

[d] Includes Arabian Islands.

[e] Includes Pondicherry.

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APPENDIX B

Rainfall Data

Appendix B provides the names of the meterological stations for which rainfall data are available from 1875. These are obtained through the courtesy of Dr. S.R. Sen and Mr. J.S. Sarma from the Indian Meterological Department and are available from the authors on request.

Rainfall data from these stations, however, suffered from one defect. There were missing observations in relation to some of those stations. The following procedure was adopted to estimate the missing observations.

If A and B are two nearby stations (decided by comparing their latitudes and longitudes), $\overline{X}_{Ai}$ and $\overline{X}_{Bi}$ be their historic averages for the ith month (generally taken as a period of 30 years length) then the missing observation for any of the two stations is estimated by using the corresponding observation from the other station and the ratio of their historic averages. For example, if station A had no rainfall record for February, 1875 but available for station B the missing observation for station A is obtained as $(\overline{X}_{A2}/\overline{X}_{B2}) \times (X_{B2})_{1875}$, the second factor being the recorded February rainfall of station B for the year 1875 (for climatological normals of observatories, see Government of India, 1967a). The time series data of these stations thus obtained are condensed to 33 rainfall subdivisions series (monthly from 1875 to 1966) by taking a simple average of the stations falling within each of the rainfall subdivisions.

From the meterologists viewpoint, use of the above rainfall data might invite criticism. The technique of measuring rainfall for any area or region from representative samples of the fall reaching the earth surface is much more complicated than the simple procedure adopted here.[1] However, the present study is primarily concerned with the relative values of the rainfall in different regions and their distribution pattern. Moreover, the averaging technique that has been adopted in constructing the rainfall indices is expected to partially cancel out errors in the rainfall data. From this viewpoint, the analysis at the national level is likely to provide better results than those for any particular locality or area.

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[1]The absolute value of the rainfall for an area is usually determined by collecting samples with the help of rain guages and estimating the mean by Thessian Polygon method, Isohytel method etc. The accuracy of the estimated mean rainfall depends upon the number and distribution of rain guages which depend upon such factors as size of the area, precipitation pattern, topography, aspect, elevation, etc. (Indian Council of Agricultural Research, 1968).

Table B1. List of meteorological stations for which rainfall data are available from 1875 and are used in computing the rainfall indices

Meteorological Subdivision	Stations[a]
1. Bay Islands	1. Port Blair (43333)
2. North Assam	1. Sibsagar (42311), 2. Dibrugarh (42312), 3. Dhubri (42404), 4. Gauhati (42411), 5. Tezpur (42415)
3. South Assam	1. Shillong (42516), 2. Silchar (42619), 3. Cheerapunji (42515), 4. Tura (42511)
4. Sub-Himalayan West Bengal	1. Jalpaiguri (42399), 2. Cooch Behar (42403), 3. Malda (42503), 4. Darjeeling (42295)
5. Gangetic West Bengal	1. Bankura (42707), 2. Berhampore(42603), 3. Burdwan (42709), 4. Krishnagar (42711), 5. Midnapore (42803)
6. Orissa	1. Balasore (42895), 2. Cuttack (42970), 3. Gopalpur (43049), 4. Puri (43503), 5. Sambalpur (42883)
7. Bihar Plain	1. Motihari (42383), 2. Darbhanga (42391), 3. Muzzafarpur (42387), 4. Patna (42491), 5. Purnea (42500)
8. Bihar Plateau	1. Hazaribagh (42699), 2. Daltonganj (42587), 3. Ranchi (42700), 4. Dumka (42599), 5. Chaibasa (42795)
9. East Uttar Pradesh	1. Allahabad (42475), 2. Bahraich (42273), 3. Gorakhpur (42379), 4. Banaras (42483), 5. Lucknow (42368)
10. West Uttar Pradesh	1. Agra (42261), 2. Bareilly (42189), 3. Jhansi (42463), 4. Meerut (42139), 5. Roorkee (42140)
11. Haryana	1. Ambala (42103), 2. New Delhi (42182)
12. Punjab	1. Ludhiana (42094), 2. Ferozepore (42096), 3. Pathankot (42058), 4. Amritsar (42071)
13. Himachal Pradesh	1. Kyelong (42063), 2. Simla (42083)
14. Jammu & Kashmir	1. Gulmarg (42536), 2. Gilgit (43516), 3. Srinagar (43540), 4. Leh (43544)
15. West Rajasthan	1. Barmer (42435), 2. Bikaner (42165), 3. Jodhpur (42339), 4. Jaisalmer (42328), 5. Philodi (42237)

Table B1. cont.

Meteorological Subdivision	Stations[a]
16. East Rajasthan	1. Ajmer (42343), 2. Jaipur (42347), 3. Kotah (42451), 4. Abu (42540), 5. Udaipur (42543)
17. West Madhya Pradesh	1. Bhopal (42668), 2. Pachmari (42767), 3. Hoshangabad (42763), 4. Indore (42755), 5. Neemuch (42547), 6. Sagar (42671)
18. East Madhya Pradesh	1. Jabalpur (42675), 2. Jagdalpur (42339), 3. Pendra (42779), 4. Raipur (42875)
19. Gujarat Region	1. Deesa (42539), 2. Ahmedabad (42647), 3. Surat (42840), 4. Broach (42841)
20. Saurashtra and Kutch	1. Dwarka (42731), 2. Veraval (42900), 3. Bhuj (42635), 4. Rajkot (42736), 5. Jamnagar (42734)
21. Konkan	1. Bombay (43057), 2. Ratnagiri (43110)
22. Madhya Maharashtra	1. Ahmednagar (43009), 2. Malegaon (42925), 3. Poona (43063), 4. Jalgaon (42857), 5. Sholapur (43117)
23. Marathwada	1. Aurangabad (43013), 2. Parbhani (43017)
24. Vidarbha	1. Akola (42933), 2. Amravati (42937), 3. Yeotmal (42943), 4. Nagpur (42867), 5. Chanda (43029)
25. Coastal Andhra Pradesh	1. Kakinada (43189), 2. Masulipatnam (43185), 3. Nellore (43245), 4. Visakhapatnam (43149), 5. Ongole (43221)
26. Telangana	1. Begumpet (43129), 2. Nizamabad (43081), 3. Hanamkonda (43087), 4. Khammam (43137)
27. Rayalseema	1. Anantapur (43237), 2. Cudappah (43241), 3. Kurnool (43213)
28. Tamil Nadu	1. Nungambakkam (43279), 2. Madurai (43259), 3. Salem (43325), 4. Cuddalore (43329), 5. Nagapattinam (43347)
29. Coastal Mysore	1. Karwar (43225), 2. Honawar (43226), 3. Mangalore (43285)
30. Interior Mysore, North	1. Belgaum (43197), 2. Bidar (43125), 3. Bijapur (43161), 4. Gulabarga (43121), 5. Raichur (43169)

Table B1. cont.

Meteorological Subdivision	Stations[a]
31. Interior Mysore, South	1. Bellary (43205), 2. Mercara (43287), 3. Hassan (43263), 4. Mysore (43291), 5. Chitaldurg (43233)
32. Kerala	1. Kozhikode (43314), 2. Cochin (43351), 3. Trivandrum (43371), 4. Palghal (43335)
33. Arabian Sea Islands	1. Amini Devi (43311), 2. Minicoy (43369)

[a]Number in parenthesis denotes the station code given by the Meteorological Department.

APPENDIX C

Construction of Rainfall Indices

For the limited objectives of the present study, two rainfall index series are constructed--one for cereals as a whole and another for rice, a principal crop of India, and the production of which is greatly influenced by the monsoons. The procedure, described in details for the construction of cereals rainfall index, is based on assigning suitable weights to the volume of rainfall in different periods within a year for each of the meteorological subdivisions. Similar procedure followed for rice is also briefly described.

A. Cereals rainfall index

Cereals production is a year round activity in India and the total production in any of the meteorological subdivisions is largely influenced by the volume of rainfall during the four monsoon periods. Through a series of mutual adjustment over years, each meteorological subdivision has evolved a particular crop calendar suitable for its soil-climatic characteristics. For some divisions, total cereals production primarily depends on southwest monsoon; for other regions all the four monsoons are important. An aggregate rainfall index to correlate with the total cereals production can, therefore, be obtained by weighting each division's rainfall during the four monsoon periods with suitable weights. Since the primary interest in this study is to examine the variations in yield and acreage and, hence, in production due to rainfall, the use of production as weights seems appropriate.

First a base period which is relatively recent and during which production fluctuations are relatively moderate is chosen. The following assumptions are then made: 1) relative contribution of the cereals produced during the four monsoon periods to any subdivision's total cereals production remains constant in any two years of same rainfall distribution; 2) relative contribution by the subdivisions/states to the state's/nation's total cereals production remain constant in any two years of same subdivision's/ state's rainfall distribution; and 3) the timings of rainfall within periods are ignored and it is assumed that the production in any monsoon period is influenced by the volume in that period.

Each subdivision's crop calendar is prepared to examine which monsoon primarily influences production of which crops. For example, consider a particular subdivision which grows the following cereals: i) March to May: autumn rice, maize, ii) June to September: winter rice, kharif jowar, bajra and ragi, iii) October to February: wheat, barley, rabi jowar and summer rice.

Let the relative contributions of cereals produced during these three periods to the subdivision's base period total cereals production be W_1, W_2, and W_3. If X_{1t}, X_{2t}, and X_{3t} denote the subdivision's corresponding rainfall total for year 't', the division's cereals rainfall index for the year 't' is defined as $(\sum_{i=1}^{3} W_i X_{it})/(\sum_{i=1}^{3} W \bar{X}_i)$, where $\bar{X}_i$s are corresponding historic rainfall averages. Rainfall indices of subdivisions falling within a state are then weighted by their corresponding base period total cereals production to derive state indices; similarly, state indices are weighted by their corresponding base period total cereals production to derive national cereals rainfall index.

The computed indices have several defects which we would like to mention here. The procedure outlined assumed no change in cereals production pattern within and among the states. This is a strong assumption but probably unavoidable and like other index series, one has to change the weights (changing the base) after some years. An alternative procedure would be to use net sown acreage instead of production as weights because the former is relatively stable. This also, however, has its own drawbacks. It ignores the basic productivity differences from region to region and makes an implicit assumption that production is proportional to acreage sown.[1]

Again the monsoon currents normally arrive in different parts of the country at different dates. The broad classification of the four monsoon periods used in the construction of the rainfall indices are, therefore, unlikely to provide sensitive results at the divisional or state levels. One way to overcome this defect is to use district crop

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[1]At the national level, the two procedures are unlikely to provide significantly different results. An earlier series that we constructed from the published rainfall data from 1950-51 with acreage as weights provided impressive results at the level (Cummings and Ray, 1969a; 1969b). With the present data also rainfall indices were constructed by using both production and acreage as weights. It was, however, found that the distribution patterns of both the series were practically the same.

calendars. This would require assigning different weights to each month of the year for the different meteorological subdivisions in the country. While this procedure is likely to increase the sensitivity of the rainfall indices for measuring production fluctuations at the regional levels, their interpretations and use at the national level for policy decisions will be rather difficult. Again, the production of any crop is assumed to be entirely dependent on one of the four monsoons. Much, however, depends on the moisture content of the soil at the time of sowing. For example, wheat is generally sown in October-November. Inadequate rain during these months hardly affects the wheat acreage if there is good rain during the month of September.

This brings out the most serious defect of the aggregative approach adopted here, viz. that distribution of rainfall by amounts and by timing is grossed over.[2] A rigorous analysis would require disaggregation of rainfall by time periods and examination of its effect at the time of sowing, flowering, maturing and harvesting of the crop.

Despite these limitations, the suggested method appeals as it is easily understandable and readily usable for policy decisions. Detail analysis of crop-rainfall relatipnship at the micro-levels, while important, loses much of its importance for decision making at the national level. For example, in fixing procurement prices, say for kharif cereals, a rough estimate about the crop prospect is generally

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[2]Obviously, it makes a difference whether rainfall is spread evenly over a period, or more specifically, falls at crucial plant growth period (i.e. the crown root and milk stages in wheat) as compared to occurring in one deluge, i.e. a flood. Oury (1967) through his Program Windex has analyzed for Punjab the effect of rainfall on output at the time of sowing, flowering, maturing and harvesting.

made from the broad rainfall distribution pattern over the country during the southwest monsoon. Regional variations in output due to rain hardly enters into the decision making. Similarly, in working out a crop insurance scheme or reserve stocks, only some location and dispersion parameters of the rainfall probability distribution are required. The averaging techniques generally used in estimating these parameters are likely to reduce the errors arising from using these indices. Finally, in this study we are concerned with the limited objective of determining the size of reserve stocks for meeting specific contigencies in probabilistic terms. An ambitious crop-rainfall analysis is beyond the scope of present work.

B. Rice rainfall index

Rice is grown in all the states of India. In some states it is practically a year round activity while in others it is grown only as kharif crop. The bulk of the production, however, comes from the kharif harvest and is influenced by rainfall during the southwest monsoon. Water requirement for rice cultivation is so high that it is difficult to meet total requirement through irrigation alone. This makes rice cultivation more monsoon dependent. Temperature and day length are generally not the constraints during the seasons when it is grown in the different states.

Following the similar procedure as in the case of cereals, rice rainfall indices are constructed at the subdivision, state and national levels. Tables in this section provide some basic data for computing the rainfall indices. The average of 1959-62 production is taken as the base. All the index series are computed in such a manner that they have same mean (100) but different dispersions.

Appendix Table C1 provides a monsoon period-wise crop production calendar for different items under cereals for different states. This is prepared from district-wise crop calendar (see Government of India, 1967b) Appendix Table C2 and Table C3 provide weights to compute divisional, state, and national rainfall index for cereals and rice. The total of the period weights for each division adds up to 100. Similarly, the totals of the division weights falling within a state and that of the state weights are all equal to 100. The 1959-62 average production is used to compute the weights.

Appendix Table C4 provides national rainfall index series for cereals and rice from 1875-76. State rainfall index series for cereals and rice are given from 1952-53 in Appendix Table C5.[3] Appendix Table C6 and Table C7 provide the state frequency distribution of cereals and rice rainfall indices. Three measures of dispersion computed for each of these frequency distributions are also given in the above tables.

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[3]Rainfall index series for cereals and rice at the meteorological subdivision and state levels from 1875-76 are available from the authors on request.

Table C1. Monsoon period-wise crop production calendar for states

State	June-Sept.	Oct.-Dec.		March-May
1. Andhra Pradesh	R(W),J(K),Bj,M,Rg,Sm	R(S),W,J(R),Br	-	R(A)
2. Assam	R(W)	W,R(S)	-	R(A),M,Sm
3. Bihar	R(A),R(W),J(K),Bj,Rg,Sm	W,Br	R(S)	-
4. Gujarat	R(W),J(K),Bj,M,Rg,Sm	W,J(R),Br	-	-
5. Jammu & Kashmir	Bj,Sm	W,Br	-	R(A),J(K),M,Rg
6. Kerala	R(W),Sm	R(S)	R(S)	R(A),Rg
7. Madhya Pradesh	R(A),J(K),Bj,M,Rg,Sm	W,J(R),Br	-	-
8. Tamil Nadu	R(A),J(K),Bj,Rg,Sm	R(W),J(R)	R(S),J(R)	-
9. Maharashtra	R(W),J(K),Bj,M,Rg,Sm	R(S),W,J(R),Br	-	-
10. Mysore	R(A),R(W),J(K),Bj,M,Rg,Sm	W,J(R),Br	R(S)	-
11. Orissa	R(A),R(W),J(K),Bj,M,Rg,Sm	W,Br	R(S)	-
12. Punjab & Haryana	R(A),R(S),J(K),Bj,M,Rg	W,Br	-	Sm
13. Rajasthan	R(A),J(K),Bj,M,Sm	W,Br	-	-
14. Uttar Pradesh	R(A),R(W),J(K),Bj,M,Rg,Sm	W,Br	R(S)	-
15. West Bengal	R(W),J(K),Sm	R(S),W,Br	-	R(A),M
16. Himachal Pradesh	R(S),J(K),Bj,Rg,Sm	W,Br	-	M

Abbreviations used: R(A) - rice, autumn; R(W) - rice, winter; R(S) - rice, summer; W - wheat; J(K) - jowar, kharif; J(R) - jowar, rabi; M - maize; Bj - Bajra; Rg - ragi; Sm - small millets; Br - barley.

Table C2. Weights to compute divisional, state, and national annual rainfall index for cereals

	Period Weights to Compute Division Rainfall Index				Division Weights to Compute State Rainfall Index	State Weights to Compute All-India Rainfall Index
	March-May	June-Sept.	Oct.-Feb.	Total		
1a. North Assam	15.44	84.19	0.37	100.00	79.1	
1b. South Assam	18.54	80.38	1.08	100.00	20.9	
					100.0	2.52
2a. Sub-Himalayan West Bengal	16.52	77.35	6.13	100.0	12.4	
2b. Gangetic West Bengal	9.14	89.44	1.42	100.0	87.6	
					100.0	7.42
3. Orissa	-	99.54	0.46	100.0	100.0	5.70
4a. Bihar Plains	-	84.50	15.50	100.0	67.4	
4b. Bihar Plateau	-	98.43	1.57	100.0	32.6	
					100.0	0.08
5a. U.P., East	-	54.06	45.94	100.0	62.8	
5b. U.P., West	-	38.64	61.36	100.0	37.2	
					100.0	15.86
6. Punjab & Haryana	-	35.09	64.91	100.0	100.0	6.30
7. Himachal Pradesh	40.89	19.81	39.30	100.0	100.0	0.47
8. Jammu & Kashmir	74.97	4.00	21.03	100.0	100.0	0.86
9a. Rajasthan, West	-	62.99	37.01	100.0	27.1	
9b. Rajasthan, East	-	50.63	49.37	100.0	72.9	
					100.0	5.68
10a. M.P., West	-	50.01	49.99	100.0	48.3	
10b. M.P., East	-	87.98	12.02	100.0	51.7	
					100.0	11.65
11a. Gujarat Region	-	81.34	18.66	100.0	77.7	
11b. Saurashtra & Kutch	-	65.89	34.11	100.0	22.3	
					100.0	3.00
12a. Konkan	-	99.34	0.66	100.0	11.8	
12b. Madhya Mahashtra	-	55.30	44.70	100.0	42.5	
12c. Marathwada	-	44.58	55.42	100.0	21.1	
12d. Vidarbha	-	80.20	19.80	100.0	24.6	
					100.0	8.08

Table C2. cont.

	Period Weights to Compute Division Rainfall Index				Division Weights to Compute State Rainfall Index	State Weights to Compute All-India
	March-May	June-Sept.	Oct.-Feb.	Total		
13a. Coastal A.P.	10.50	80.50	9.00	100.0	47.8	
13b. Telengana	5.67	70.43	23.90	100.0	34.1	
13c. Rayalseem	4.11	77.42	18.47	100.0	18.1	
					100.0	9.56
14. Tamil Nadu	-	74.77	25.23	100.0	100.0	6.88
15a. Coastal Mysore	-	97.90	2.10	100.0	9.1	
15b. Mysore North	-	57.51	42.49	100.0	40.4	
15c. Mysore, South	-	97.09	2.91	100.0	50.5	
					100.0	5.36
16. Kerala	45.36	43.85	10.79	100.0	100.0	1.58

Table C3. Weights to compute divisional, state, and national annual rainfall index for rice

	Period Weights to Compute Division Rainfall Index					Division Weights to Compute State Rainfall Index	State Weights to Compute All-India Rainfall Index
	March-May	June-Sept.	Oct.-Dec.	Jan.-Feb.	Total		
1a. North Assam	15.3	84.5	0.2	-	100.0	79.3	
1b. South Assam	17.2	81.7	1.1	-	100.0	20.7	
						100.0	5.12
2a. Sub-Himalayan West Bengal	14.6	82.8	2.6	-	100.0	11.7	
2b. Gangetic West Bengal	4.1	90.6	5.3	-	100.0	88.3	
						100.0	14.88
3. Orissa	-	99.6	-	0.4	100.0	100.0	11.47
4a. Bihar Plains	-	100.0	-	-	100.0	61.0	
4b. Bihar Plateau	-	100.0	-	-	100.0	39.0	
						100.0	13.18
5a. U.P., East	-	99.8	-	0.2	100.0	76.4	
5b. U.P., West	-	100.0	-	-	100.0	23.6	
						100.0	9.20
6. Punjab & Haryana	-	100.0	-	-	100.0	100.0	1.35
7. Himachal Pradesh	-	100.0	-	-	100.0	100.0	0.13
8. Jammu & Kashmir	100.0	-	-	-	100.0	100.0	0.71
9a. Rajasthan, West	-	100.0	-	-	100.0	4.2	
9b. Rajasthan, East	-	100.0	-	-	100.0	95.8	
						100.0	0.28
10a. M.P., West	-	100.0	-	-	100.0	9.1	
10b. M.P., East	-	100.0	-	-	100.0	90.9	
						100.0	10.44
11a. Gujarat Region	-	100.0	-	-	100.0	94.7	
11b. Saurashtra & Kutch	-	100.0	-	-	100.0	5.3	
						100.0	1.20

Table C3. cont.

	Period Weights to Compute Division Rainfall Index					Division Weights to Compute State Rainfall Index	State Weights to Compute All-India Rainfall Index
	March-May	June-Sept.	Oct.-Dec.	Jan.-Feb.	Total		
12a. Konkan	-	99.2	-	0.8	100.0	40.4	
12b. Madhya Maharashtra	-	100.0	-	-	100.0	20.4	
12c. Marathwada	-	93.4	-	6.6	100.0	3.4	
12d. Vidarbha	-	100.0	-	-	100.0	35.8	
						100.0	4.04
13a. Coastal A.P.	13.3	79.6	7.1	-	100.0	62.5	
13b. Telengana	11.4	69.1	19.5	-	100.0	28.0	
13c. Rayalaseema	13.0	64.5	64.5	-	100.0	9.5	
						100.0	11.85
14. Tamil Nadu	-	67.0	27.2	5.0	100.0	100.0	8.90
15a. Coastal Mysore	-	97.9	-	2.1	100.0	24.6	
15b. Mysore, North	98.8	98.8	-	1.2	100.0	18.9	
15c. Mysore, South	-	96.4	-	3.6	100.0	56.5	
						100.0	4.05
16. Kerala	45.0	44.0	11.0	-	100.0	100.0	3.20

Table C4. National rainfall index (normal = 100)

Decade Beginning With	Crop Year Within the Decade 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-0
					Cereals					
1870	-	-	-	-	-	102	90	75	102	109
1880	94	102	103	97	109	100	108	104	94	104
1890	108	88	123	118	116	94	95	98	101	73
1900	106	81	91	104	84	83	105	82	102	107
1910	109	85	92	91	108	95	114	120	77	103
1920	84	101	107	93	102	95	103	101	91	96
1930	95	103	92	112	102	95	109	97	106	89
1940	98	89	107	102	109	97	107	105	104	105
1950	100	82	88	110	102	117	126	95	104	103
1960	105	118	97	99	110	84	-	-	-	-
					Rice					
1870	-	-	-	-	-	100	88	79	101	108
1880	99	108	100	96	104	103	106	79	94	107
1890	109	89	106	113	104	100	101	95	109	86
1900	104	86	96	100	86	92	102	88	101	109
1910	105	93	94	99	105	100	108	111	91	104
1920	92	104	112	91	102	102	104	96	95	99
1930	98	99	91	102	96	95	112	95	107	96
1940	101	95	103	104	100	93	105	103	102	105
1950	100	87	90	108	99	105	120	96	97	97
1960	106	112	94	100	108	90	-	-	-	-

Table C5. State rainfall index (normal = 100)

	1952-53	1953-54	1954-55	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
							Cereals						
1. Assam	97	108	108	114	102	88	80	82	136	83	76	114	97
2. West Bengal	96	111	83	91	115	98	86	95	89	88	78	88	94
3. Orissa	103	94	90	105	143	76	103	83	115	140	94	91	123
4. Bihar	103	116	91	100	112	95	79	77	100	84	82	104	93
5. Uttar Pradesh	92	119	93	137	134	85	110	80	123	122	101	106	103
6. Punjab & Haryana	86	131	100	175	145	102	145	111	111	129	114	83	130
7. Himachal Pradesh	93	136	93	114	117	123	121	102	102	101	96	131	94
8. Jammu & Kashmir	102	116	79	167	137	172	100	88	114	104	82	162	102
9. Rajasthan	113	101	101	124	148	90	114	124	81	136	94	81	109
10. Madhya Pradesh	97	97	101	113	115	82	103	115	91	141	87	88	110
11. Gujarat	87	131	164	78	134	75	113	176	76	135	77	97	134
12. Maharashtra	68	104	113	123	120	109	115	119	90	114	99	105	102
13. Andhra Pradesh	63	108	115	114	132	117	115	121	104	116	116	103	124
14. Tamil Nadu	70	106	102	93	115	100	83	81	136	102	110	116	110
15. Mysore	80	117	112	111	134	94	106	130	90	131	102	96	125
16. Kerala	75	85	107	118	95	106	94	133	123	160	113	92	97
							Rice						
1. Assam	97	108	108	114	102	88	79	82	136	83	77	114	97
2. West Bengal	96	112	83	91	115	98	86	96	89	88	78	87	94
3. Orissa	103	94	90	104	143	76	103	83	115	140	94	91	133
4. Bihar	103	117	91	98	110	95	80	77	100	85	82	102	93
5. Uttar Pradesh	94	126	86	127	111	88	100	73	113	108	111	115	108
6. Punjab & Haryana	88	124	105	108	104	107	145	133	104	136	138	91	154
7. Himachal Pradesh	76	121	127	110	99	107	120	113	93	87	109	94	89
8. Jammu & Kashmir	116	104	87	182	137	179	89	78	126	114	86	180	98
9. Rajasthan	121	97	99	122	134	95	120	120	84	136	97	88	108
10. Madhya Pradesh	106	104	100	103	120	86	103	107	88	136	74	87	106
11. Gujarat	84	126	167	81	129	73	108	162	75	128	73	101	134
12. Maharashtra	72	111	133	123	113	120	124	120	97	108	97	113	110
13. Andhra Pradesh	65	105	120	111	136	119	114	120	105	119	119	101	124
14. Tamil Nadu	70	104	101	92	116	102	83	83	135	100	107	120	110
15. Mysore	78	109	112	104	122	85	107	134	90	140	95	93	117
16. Kerala	74	85	107	118	95	106	94	133	122	159	113	93	97

Table C6. Frequency distribution of state cereals rainfall index

	Frequency of Rainfall Index Within Class Interval[a]						Coefficient of		
	≤ 80	≤ 90	≤ 100	≤ 110	≤ 120	> 120	Variation (percent)	Skewness	Kurtosis
North									
Jammu & Kashmir	23.53	11.76	16.48	15.30	12.93	20.00	24.37	-0.03	-0.73
Punjab & Haryana	25.00	15.91	18.18	9.09	7.96	23.86	23.34	0.38	-0.90
Rajasthan	19.24	20.51	14.10	11.54	14.09	20.52	22.91	0.10	-0.74
Uttar Pradesh	13.19	13.18	18.68	28.58	13.18	18.19	18.80	-0.19	-0.03
East									
Assam	4.40	15.38	32.97	30.77	13.18	3.30	11.38	0.01	-0.27
Bihar	10.99	14.28	27.48	24.17	12.09	10.99	14.54	0.07	-0.73
Orissa	15.38	13.19	25.28	21.97	9.89	14.29	15.90	0.10	-0.92
West Bengal	5.49	20.88	31.87	14.29	20.88	6.59	13.52	0.19	-0.87
West									
Gujarat	16.89	14.28	15.59	16.89	11.69	24.66	21.48	0	-0.85
Madhya Pradesh	14.28	13.19	21.98	23.08	20.87	6.60	17.13	0.06	0.20
Maharashtra	15.38	19.78	17.59	20.88	15.38	10.99	19.52	0	-0.10
South									
Andhra Pradesh	15.90	14.78	23.88	15.90	15.92	13.62	19.24	0.01	-0.59
Kerala	13.19	17.58	21.98	25.27	13.19	8.79	17.19	0.50	0.30
Mysore	7.69	19.78	23.08	27.47	12.09	9.89	15.47	0	0.51
Tamil Nadu	14.28	16.49	15.38	24.18	16.48	13.19	17.57	-0.13	-0.67
All-India	3.30	13.18	28.57	43.96	7.69	3.30	10.31	-0.14	0.25

[a]Extreme observations are omitted in computing the frequencies. Each row adds up to 100.

Table C7. Frequency distribution of state rice rainfall index

	Frequency of Rainfall Index Within Class Interval[a] ≤ 80	≤ 90	≤ 100	≤ 110	≤ 120	> 120	Coefficient of Variation (percent)	Coefficient of Skewness	Coefficient of Kurtosis
North									
Jammu & Kashmir	21.11	7.04	16.90	15.49	12.69	26.77	24.64	-0.23	-0.68
Punjab & Haryana	28.57	11.90	10.71	21.43	8.33	19.06	24.88	0.11	-0.84
Rajasthan	18.42	23.69	11.84	13.16	11.84	21.05	22.49	0.19	-0.87
Uttar Pradesh	13.48	11.24	24.72	23.60	13.48	13.48	17.63	0.27	-0.01
East									
Assam	3.37	15.73	33.71	32.58	12.36	2.25	10.77	0	0.23
Bihar	8.89	14.44	30.00	24.45	13.33	8.89	13.73	0.03	-0.60
Orissa	15.91	14.77	26.14	21.59	10.23	11.36	15.63	0.16	-0.85
West Bengal	5.56	24.44	31.11	12.22	21.11	5.56	13.64	0.27	-0.91
West									
Gujarat	16.46	16.46	10.13	18.99	10.12	27.84	22.33	-0.06	-0.78
Madhya Pradesh	13.34	12.22	25.56	26.67	11.11	11.10	16.79	0	-0.18
Maharashtra	12.37	13.48	20.22	24.71	17.98	11.24	16.67	-0.02	-0.41
South									
Andhra Pradesh	15.38	19.79	17.58	17.58	15.38	14.29	20.21	0.35	-0.39
Kerala	13.19	17.58	21.98	26.36	12.09	8.80	17.14	0.51	0.39
Mysore	8.79	19.78	27.48	17.58	17.58	8.79	15.81	0.59	0.15
Tamilnadu	14.29	16.48	21.98	20.88	13.19	13.18	17.84	0.16	0.52
All-India	-	10.00	42.22	41.11	6.67	-	7.66	-0.03	0.38

[a]Extreme observations are omitted in computing the frequencies. Each row adds up to 100.

Table C8. Relevant variables for analysis of rainfall effect on crop output at national level

	Rainfall Index (Normal=100)[a] (W)	Price Index[b] (1952-53=100)	Index of Area[c] (1949-50=100) (A)	Index of Production[c] (1949-50=100) (X)	Index of Production[c] (1949-50=100) (Y)
			Cereals		
1949-50	104.6	93.0	100.0	100.0	100.0
1950-51	99.7	102.0	99.4	90.3	90.8
1951-52	81.9	99.0	99.3	91.2	91.8
1952-53	88.2	100.0	104.5	101.4	97.0
1953-54	110.1	84.0	111.0	120.1	108.2
1954-55	101.6	73.0	109.1	114.5	104.9
1955-56	116.8	92.0	110.7	114.9	103.8
1956-57	126.2	102.0	111.4	120.5	108.2
1957-58	94.9	105.0	110.3	110.1	99.8
1958-59	104.4	104.0	114.7	129.8	113.2
1959-60	103.3	105.0	115.4	128.9	111.7
1960-61	104.6	102.0	116.7	138.3	118.5
1961-62	118.0	106.0	118.1	143.1	121.2
1962-63	96.6	112.0	118.8	135.9	114.4
1963-64	98.6	134.0	118.2	141.4	119.6
1964-65	109.7	145.0	119.5	154.4	129.3
			Rice		
1949-50	105.0	91.0	100.0	100.0	100.0
1950-51	100.0	104.0	100.9	87.9	87.1
1951-52	87.0	100.0	97.7	90.1	92.2
1952-53	90.0	102.0	98.2	96.8	98.6
1953-54	108.0	86.0	102.5	118.6	115.7
1954-55	99.0	76.0	100.6	105.8	105.2
1955-56	105.0	93.0	103.1	114.2	110.8
1956-57	120.0	104.0	105.4	120.4	114.2
1957-58	96.0	108.0	105.5	105.7	100.2
1958-59	97.0	102.0	108.3	127.6	117.8
1959-60	97.0	109.0	110.4	126.2	114.3
1960-61	106.0	105.0	111.4	137.7	123.6
1961-62	112.0	109.0	113.5	142.4	125.5
1962-63	94.0	122.0	116.8	132.6	113.5
1963-64	110.0	133.0	116.7	147.0	126.0
1964-65	108.0	135.0	118.8	156.2	131.5

[a] Source: Appendix Table C4.

[b] Government of India (1967c). Price index for 1949-50 refers to the calendar year average of 1950, and so on.

[c] Estimates of area and production of principal crops in India, 1968-69 (Summary Tables) (Government of India, 1969b).

Table C9. Effect of rainfall on cereals area, production and productivity

	Equation Number	Estimated Coefficient of: Constant	T	W_t	W_t^2	Log W_t	R^2	D-Statistic
Area(A)	(1)	89.14	1.30*	0.12			0.93	1.04
			(0.12)	(0.05)				
	(2)	32.99	1.23*	1.21	-0.0052		0.94	0.99
			(0.12)	(0.65)	(0.0031)			
	(3)	1.76	0.0051*			0.12*	0.92	0.98
			(0.0005)			(0.04)		
Production(X)	(1)	55.92	3.76*	0.35*			0.93	1.32
			(0.34)	(0.13)				
	(2)	-63.47	3.59*	2.68	-0.0111		0.94	1.53
			(0.36)	(1.94)	(0.0092)			
	(3)	1.25	0.0134*			0.36*	0.93	1.20
			(0.0012)			(0.12)		
Yield(Y)	(1)	68.66	2.11*	0.23*			0.89	1.46
			(0.24)	(0.09)				
	(2)	7.90	2.02*	1.41	-0.0056		0.90	1.63
			(0.27)	(1.44)	(0.0068)			
	(3)	1.49	0.0084*			0.24*	0.90	1.45
			(0.0010)			(0.09)		

*Significant at 5 percent level.

Figure in parentheses denotes standard error.

Table C10. Effect of rainfall on rice area, production and productivity

	Equation Number	Estimated Coefficient of: Constant	T	W_t	W_t^2	Log W_t	R^2	D-Statistic
Area(A)	(1)	90.90	1.41*	0.05			0.96	1.23
			(0.09)	(0.05)				
	(2)	38.93	1.37*	1.06	-0.0049		0.96	1.11
			(0.10)	(0.95)	(0.0045)			
	(3)	1.87	0.0057*			0.06	0.96	1.29
			(0.0004)			(0.04)		
Production(X)	(1)	28.29	3.87*	0.60*			0.92	1.89
			(0.38)	(0.19)				
	(2)	-138.16	3.77*	3.86	-0.1557		0.93	1.99
			(0.40)	(3.91)	(0.0189)			
	(3)	0.83	0.0141*			0.56*	0.92	1.82
			(0.0014)			(0.17)		
Yield(Y)	(1)	40.72	2.14*	0.53*			0.83	1.71
			(0.35)	(0.18)				
	(2)	-72.48	2.07*	2.74	-0.0107		0.84	1.79
			(0.38)	(3.72)	(0.0179)			
	(3)	0.96	0.0085*			0.50*	0.82	1.59
			(0.0015)			(0.18)		

*Significant at 5 percent level.

Figure in parentheses denotes standard error.

Table C11. Production fluctuations around the trend: estimated equations with lagged variables[a]

Equation No.	Estimated Coefficient of (logarithm of the variables) Constant	$W_{r,t}$	$P_{r,t-1}$	$W_{r,t-1}$	$Y_{r,t-1}$	$X_{r,t-1}$	R^2	D-Statistic
				(cereals)				
1.	1.2024	0.4065*					0.60	1.79
		(0.0953)						
2.	1.6660	0.3545*		-0.1799*			0.72	2.28
		(0.0894)		(0.0808)				
3.	1.9147	0.4093*			-0.3580		0.70	1.48
		(0.0870)			(0.1939)			
4.	0.8226	0.4225*	0.1730				0.66	1.68
		(0.0929)	(0.1258)					
5.	1.2886	0.3707*	0.1695	-0.1779*			0.76	1.84
		(0.0850)	(0.1103)	(0.0857)				
6.	1.5394	0.4201*	0.1210		-0.3029		0.72	1.33
		(0.0879)	(0.1242)		(0.2024)			
7.	1.3281	0.4202*	0.1255			-0.2017	0.70	1.38
		(0.0907)	(0.1291)			(0.1692)		
				(rice)				
1.	0.7864	0.6149*					0.60	2.42
		(0.1452)						
2.	1.6468	0.5904*		-0.3153*			0.74	2.70
		(0.1316)		(0.1308)				
3.	1.5555	0.6012*			-0.3695*		0.74	1.98
		(0.1215)			(0.1486)			
4.	0.5253	0.6116*	0.1331				0.62	2.45
		(0.1480)	(0.1768)					
5.	1.4117	0.4999*	0.1111	-0.3090*			0.75	2.64
		(0.1343)	(0.1501)	(0.1338)				
6.	1.5377	0.6011*	0.0066		-0.3671*		0.74	1.98
		(0.1274)	(0.1626)		(0.1665)			
7.	1.5705	0.5905*	0.0137			-0.3791*		
		(0.1194)	(0.1494)			(0.1436)		

[a]All equations are in double logarithmic form. Dependent variable is log $X_{r,t}$

*Significant at 5 percent level.

Figure in parenthesis denotes the standard error.

APPENDIX D

Table D1. Standard deviations of the estimates given in Table 22 (Rs. million)

		Scheme-A				Scheme-B				Scheme-C			
		$M_1=5.0$ $M_2=0.0$	$M_1=7.0$ $M_2=0.0$	$M_1=9.0$ $M_2=0.0$	$M_1=11.0$ $M_2=0.0$	$M_1=5.0$ $M_2=0.0$	$M_1=7.0$ $M_2=0.0$	$M_1=9.0$ $M_2=0.0$	$M_1=11.0$ $M_2=0.0$	$M_1=5.0$ $M_2=2.0$	$M_1=7.0$ $M_2=2.5$	$M_1=9.0$ $M_2=3.0$	$M_1=11.0$ $M_2=3.5$
	Imports	-	-	-	-	39	25	14	8	55	43	31	22
	Exports	-	-	-	-	52	52	52	52	56	53	52	52
	Δ Farm Inc.	75	101	124	138	269	269	269	269	269	269	269	269
(A)	Fin. Ben.[a]	36	49	59	65	37	51	62	69	24	34	44	54
	Fin. Ben.[b]	42	58	71	79	42	58	61	79	26	38	50	62
	Fin. Ben.[c]	37	49	58	64	37	49	59	65	24	34	43	51
	Fin. Ben.[d]	35	47	57	63	35	47	57	63	23	32	41	50
	Imports	-	-	-	-	30	17	9	4	46	34	23	15
	Exports	-	-	-	-	47	47	47	47	49	47	47	47
	Δ Farm Inc.	79	105	122	130	244	244	244	244	244	244	244	244
(B)	Fin. Ben.[a]	38	50	58	62	40	52	61	65	25	36	46	55
	Fin. Ben.[b]	46	61	71	76	45	61	71	76	27	41	53	64
	Fin. Ben.[c]	38	49	57	61	38	50	57	61	25	35	44	52
	Fin. Ben.[d]	37	48	56	60	37	48	56	60	23	33	43	51
	Imports	-	-	-	-	23	12	5	2	38	26	17	10
	Exports	-	-	-	-	43	43	43	43	44	43	43	43
	Δ Farm Inc.	82	104	115	120	221	221	221	221	221	221	221	221
(C)	Fin. Ben.[a]	39	49	54	56	41	52	58	60	26	38	47	54
	Fin. Ben.[b]	48	62	69	71	48	62	69	71	30	44	56	64
	Fin. Ben.[c]	39	49	54	56	39	49	54	56	26	36	45	51
	Fin. Ben.[d]	38	48	53	56	38	49	54	56	24	35	44	50
	Imports	-	-	-	-	16	7	3	1	31	19	11	6
	Exports	-	-	-	-	39	39	39	39	40	39	39	39
	Δ Farm Inc.	84	100	107	109	200	200	200	200	200	200	200	200
(D)	Fin. Ben.[a]	40	47	50	51	42	50	54	55	28	39	47	52
	Fin. Ben.[b]	51	61	65	66	51	61	65	66	33	47	57	62
	Fin. Ben.[c]	40	47	50	51	40	48	51	52	27	37	45	49
	Fin. Ben.[d]	40	47	50	51	39	47	50	52	26	37	44	48

[a]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[b]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D2. Standard deviations of the estimates given in Table 23 (Rs. million)

		Scheme-A				Scheme-B				Scheme-C			
		M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.5	M_1=3.0 M_2=1.0	M_1=4.0 M_2=1.5	M_1=5.0 M_2=2.0
	Imports	-	-	-	-	14	6	2	Neg.	20	14	10	6
	Exports	-	-	-	-	30	30	30	30	31	30	30	30
	Δ Farm Inc.	24	29	31	32	53	53	53	53	53	53	53	53
(A)	Fin. Ben.[a]	18	22	24	24	19	24	25	26	16	19	22	24
	Fin. Ben.[b]	22	28	29	30	22	28	29	30	18	22	25	28
	Fin. Ben.[c]	18	22	23	24	18	22	23	24	15	18	20	22
	Fin. Ben.[d]	18	22	23	24	18	22	23	24	14	18	20	22
	Imports	-	-	-	-	5	1	0	0	8	5	2	1
	Exports	-	-	-	-	20	20	20	20	21	20	20	20
	Δ Farm Inc.	20	22	22	22	36	36	36	36	36	36	36	36
(B)	Fin. Ben.[a]	16	17	17	17	17	18	18	18	15	17	18	18
	Fin. Ben.[b]	20	21	22	22	20	21	22	22	17	20	21	21
	Fin. Ben.[c]	15	17	17	17	15	17	17	17	14	15	16	17
	Fin. Ben.[d]	15	17	17	17	15	17	17	17	14	15	16	17
	Imports	-	-	-	-	1	0	0	0	2	1	0	0
	Exports	-	-	-	-	11	11	11	11	11	11	11	11
	Δ Farm Inc.	13	13	13	13	19	19	19	19	19	19	19	19
(C)	Fin. Ben.[a]	10	10	10	10	11	11	11	11	10	10	11	11
	Fin. Ben.[b]	13	13	13	13	13	13	13	13	12	13	13	13
	Fin. Ben.[c]	10	10	10	10	10	10	10	10	9	10	10	10
	Fin. Ben.[d]	10	10	10	10	10	10	10	10	10	10	10	10
	Imports	-	-	-	-	0	0	0	0	0	0	0	0
	Exports	-	-	-	-	5	5	5	5	5	5	5	5
	Δ Farm Inc.	6	6	6	6	9	9	9	9	9	9	9	9
(D)	Fin. Ben.[a]	5	5	5	5	5	5	5	5	5	5	5	5
	Fin. Ben.[b]	6	6	6	6	6	6	6	6	6	6	6	6
	Fin. Ben.[c]	5	5	5	5	5	5	5	5	5	5	5	5
	Fin. Ben.[d]	5	5	5	5	5	5	5	5	5	5	5	5

[a] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[b] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D3. Expected present values of storage benefits for cereals (Rs. million): stabilization around $\bar{P}$=Rs. 750 per ton[a]

		Scheme-A				Scheme-B				Scheme-C			
		M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2= 0.0	M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2=0.0	M_1=5.0 M_2=2.0	M_1=7.0 M_2=2.5	M_1=9.0 M_2=3.0	M_1=11.0 M_2=3.5
	Initial Inv.	-4,500	-6,300	-8,100	-9,900	-4,500	-6,300	-8,100	-9,900	-4,500	-6,300	-8,100	-9,900
	Imports	-	-	-	-	-776	-300	-104	-33	-1,767	-963	-490	-233
	Exports	-	-	-	-	1,744	1,630	1,614	1,612	2,167	1,809	1,663	1,621
	Δ Farm Inc.	-2,890	-3,733	-4,190	-4,371	1,145	1,145	1,145	1,145	1,145	1,145	1,145	1,145
(A)	Fin. Ben.[b]	895	1,258	1,465	1,549	1,201	1,611	1,835	1,924	678	1,075	1,426	1,682
	Fin. Ben.[c]	2,241	2,727	2,985	3,087	2,161	2,679	2,947	3,052	1,415	1,993	2,451	2,765
	Fin. Ben.[d]	774	1,097	1,287	1,365	694	1,048	1,249	1,330	289	591	886	1,111
	Fin. Ben.[e]	1,062	1,398	1,591	1,669	982	1,350	1,553	1,634	527	872	1,184	1,414
	Imports	-	-	-	-	-477	-158	-47	-12	-1,222	-616	-280	-117
	Exports	-	-	-	-	1,444	1,392	1,389	1,388	1,703	1,483	1,406	1,390
	Δ Farm Inc.	-2,814	-3,461	-3,740	-3,831	976	976	976	976	976	976	976	976
(B)	Fin. Ben.[b]	1,018	1,307	1,436	1,478	1,269	1,589	1,727	1,771	768	1,158	1,456	1,638
	Fin. Ben.[c]	2,140	2,516	2,675	2,727	2,087	2,483	2,647	2,700	1,409	1,943	2,321	2,542
	Fin. Ben.[d]	955	1,221	1,342	1,382	903	1,188	1,314	1,355	480	806	1,068	1,233
	Fin. Ben.[e]	1,170	1,442	1,563	1,603	1,117	1,409	1,535	1,576	664	1,016	1,287	1,454
	Imports	-	-	-	-	-275	-77	-19	-4	-821	-369	-148	-54
	Exports	-	-	-	-	1,207	1,188	1,187	1,187	1,359	1,225	1,192	1,188
	Δ Farm Inc.	-2,651	-3,097	-3,245	-3,284	851	851	851	851	851	851	851	851
(C)	Fin. Ben.[b]	1,058	1,262	1,331	1,349	1,259	1,481	1,555	1,574	822	1,170	1,396	1,511
	Fin. Ben.[c]	1,973	2,234	2,319	2,342	1,939	2,210	2,299	2,321	1,365	1,826	2,108	2,246
	Fin. Ben.[d]	1,037	1,230	1,295	1,312	1,003	1,206	1,275	1,292	617	922	1,128	1,234
	Fin. Ben.[e]	1,191	1,385	1,451	1,468	1,157	1,362	1,430	1,448	752	1,074	1,283	1,390
	Imports	-	-	-	-	-147	-32	-8	-1	-521	-204	-71	-22
	Exports	-	-	-	-	1,001	994	994	994	1,081	1,008	995	994
	Δ Farm Inc.	-2,399	-2,670	-2,732	-2,750	727	727	727	727	727	727	727	727
(D)	Fin. Ben.[b]	1,020	1,146	1,175	1,183	1,178	1,313	1,344	1,353	833	1,115	1,265	1,326
	Fin. Ben.[c]	1,750	1,909	1,946	1,957	1,728	1,894	1,931	1,942	1,285	1,650	1,835	1,909
	Fin. Ben.[d]	1,027	1,147	1,175	1,183	1,006	1,132	1,161	1,169	691	947	1,087	1,143
	Fin. Ben.[e]	1,133	1,254	1,282	1,289	1,111	1,238	1,267	1,275	787	1,052	1,193	1,250

[a]Storage rules aimed at limiting price fluctuations at 2,3,4, and 5 percent of the desired mean price $\bar{P}$=Rs. 750 per ton are denoted by (A), (B), (C), and (D), respectively. For standard deviations of the estimates, see Appendix Table D4.

[b]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[e]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D4. Standard deviations of the estimates given in Appendix Table D3 (Rs. million)

		Scheme-A				Scheme-B				Scheme-C			
		M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2=0.0	M_1=5.0 M_2=2.0	M_1=7.0 M_2=2.5	M_1=9.0 M_2=3.0	M_1=11.0 M_2=3.5
	Imports	–	–	–	–	39	25	14	8	55	43	31	22
	Exports	–	–	–	–	52	52	52	52	56	53	52	52
	Δ Farm Inc.	70	95	116	129	252	252	252	252	252	252	252	252
(A)	Fin. Ben.[a]	35	46	55	61	35	48	58	65	23	32	42	51
	Fin. Ben.[b]	40	55	67	75	40	55	68	75	25	36	48	58
	Fin. Ben.[c]	35	46	55	60	35	46	55	61	23	32	41	49
	Fin. Ben.[d]	33	44	53	59	33	44	53	59	21	30	39	47
	Imports	–	–	–	–	30	17	9	4	46	34	23	15
	Exports	–	–	–	–	47	47	47	47	49	47	47	47
	Δ Farm Inc.	74	98	114	122	228	228	228	228	228	228	228	228
(B)	Fin. Ben.[a]	36	47	54	58	37	49	57	61	23	34	43	52
	Fin. Ben.[b]	43	58	67	72	43	58	68	72	26	39	50	61
	Fin. Ben.[c]	36	46	53	57	36	47	54	57	24	33	42	49
	Fin. Ben.[d]	34	45	52	56	35	45	53	56	22	31	40	48
	Imports	–	–	–	–	23	12	5	2	38	26	17	10
	Exports	–	–	–	–	43	43	43	43	44	43	43	43
	Δ Farm Inc.	77	98	108	112	208	208	208	208	208	208	208	208
(C)	Fin. Ben.[a]	37	46	51	53	39	49	54	56	25	35	44	51
	Fin. Ben.[b]	46	59	65	67	46	59	65	68	28	42	53	61
	Fin. Ben.[c]	37	46	50	52	37	46	51	53	24	34	42	48
	Fin. Ben.[d]	36	45	50	52	36	45	50	52	23	33	41	47
	Imports	–	–	–	–	16	7	3	1	31	19	11	6
	Exports	–	–	–	–	39	39	39	39	40	39	39	39
	Δ Farm Inc.	79	94	100	102	187	187	187	187	187	187	187	187
(D)	Fin. Ben.[a]	37	44	47	48	39	47	50	51	26	37	44	48
	Fin. Ben.[b]	48	58	61	63	48	58	62	63	31	44	54	59
	Fin. Ben.[c]	37	44	47	48	37	45	47	48	25	35	42	45
	Fin. Ben.[d]	37	44	47	48	37	44	47	48	25	34	41	45

[a]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[b]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D5. Expected present values of storage benefits for cereals (Rs. million): stabilization around $\bar{P}$=Rs. 850 per ton[a]

	Scheme-A				Scheme-B				Scheme-C			
	M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2=0.0	M_1=5.0 M_2=2.0	M_1=7.0 M_2=2.5	M_1=9.0 M_2=3.0	M_1=11.0 M_2=3 5
Initial Inv.	-5,000	-7,000	-9,000	-11,000	-5,000	-7,000	-9,000	-11,000	-5,000	-7,000	-9,000	-11,000
Imports	-	-	-	-	-776	-300	-104	-33	-1,767	-963	-490	-233
Exports	-	-	-	-	1,744	1,630	1,613	1,612	2,167	1,809	1,663	1,621
Δ Farm Inc.	-3,275	-4,231	4,748	-4,954	1,297	1,297	1,297	1,297	1,297	1,297	1,297	1,297
(A) Fin. Ben.[b]	1,163	1,585	1,823	1,918	1,463	1,933	2,188	2,289	853	1,319	1,722	2,014
Fin. Ben.[c]	2,493	3,032	3,319	3,432	2,403	2,978	3,276	3,392	1,574	2,217	2,725	3,073
Fin. Ben.[d]	1,026	1,402	1,621	1,710	936	1,347	1,578	1,670	448	814	1,160	1,420
Fin. Ben.[e]	1,314	1,704	1,924	2,014	1,224	1,649	1,882	1,974	686	1,095	1,457	1,723
Imports	-	-	-	-	-477	-158	-47	-12	-1,222	-616	-280	-117
Exports	-	-	-	-	1,444	1,392	1,389	1,389	1,703	1,483	1,406	1,390
Δ Farm Inc.	-3,190	-3,923	-4,239	-4,342	1,106	1,106	1,106	1,106	1,106	1,106	1,106	1,106
(B) Fin. Ben.[b]	1,267	1,601	1,748	1,796	1,515	1,879	2,035	2,086	935	1,387	1,728	1,935
Fin. Ben.[c]	2,381	2,799	2,975	3,033	2,322	2,760	2,943	3,002	1,568	2,161	2,581	2,826
Fin. Ben.[d]	1,197	1,504	1,642	1,688	1,137	1,466	1,610	1,657	639	1,024	1,328	1,517
Fin. Ben.[e]	1,411	1,725	1,863	1,909	1,351	1,687	1,831	1,878	823	1,234	1,548	1,738
Imports	-	-	-	-	-275	-77	-19	-4	-821	-369	-148	-54
Exports	-	-	-	-	1,207	1,188	1,187	1,187	1,359	1,225	1,192	1,188
Δ Farm Inc.	-3,005	-3,510	-3,678	-3,722	964	964	964	964	964	964	964	964
(C) Fin. Ben.[b]	1,283	1,518	1,597	1,617	1,482	1,734	1,818	1,839	979	1,380	1,637	1,768
Fin. Ben.[c]	2,196	2,485	2,580	2,605	2,157	2,459	2,557	2,582	1,519	2,032	2,344	2,498
Fin. Ben.[d]	1,260	1,481	1,556	1,575	1,221	1,455	1,532	1,553	771	1,128	1,365	1,486
Fin. Ben.[e]	1,413	1,637	1,712	1,731	1,375	1,610	1,688	1,709	906	1,279	1,520	1,642
Imports	-	-	-	-	-147	-32	-8	-1	-521	-204	-71	-22
Exports	-	-	-	-	1,001	994	994	994	1,081	1,008	995	994
Δ Farm Inc.	-2,719	-3,026	-3,096	-3,116	824	824	824	824	824	824	824	824
(D) Fin. Ben.[b]	1,217	1,361	1,394	1,403	1,372	1,526	1,561	1,571	978	1,300	1,471	1,540
Fin. Ben.[c]	1,947	2,124	2,165	2,176	1,922	2,107	2,148	2,160	1,430	1,836	2,041	2,123
Fin. Ben.[d]	1,225	1,362	1,394	1,403	1,200	1,345	1,378	1,387	836	1,133	1,293	1,358
Fin. Ben.[e]	1,330	1,469	1,500	1,510	1,305	1,451	1,484	1,493	932	1,238	1,399	1,464

[a]Storage rules aimed at limiting price fluctuation at 2,3,4, and 5 percent of the desired mean price $\bar{P}$=Rs. 850 per ton are denoted by (A), (B), (C) and (D), respectively. For standard deviations of the estimates, see Appendix Table D6.

[b]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[e]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D6. Standard deviations of the estimates given in Appendix Table D5.

		Scheme-A				Scheme-B				Scheme-C			
		M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2=0.0	M_1=5.0 M_2=2.0	M_1=7.0 M_2=2.5	M_1=9.0 M_2=3.0	M_1=11.0 M_2=3.5
	Imports	-	-	-	-	39	25	14	8	55	43	31	22
	Exports	-	-	-	-	52	52	52	52	56	53	52	52
	Δ Farm Inc.	79	108	132	147	286	286	286	286	286	286	286	286
(A)	Fin. Ben.[a]	38	52	63	69	40	54	66	73	25	36	47	57
	Fin. Ben.[b]	45	61	75	83	44	61	75	84	28	40	53	65
	Fin. Ben.[c]	39	51	62	68	39	52	62	69	26	36	45	54
	Fin. Ben.[d]	37	50	60	67	37	50	61	67	24	34	44	53
	Imports	-	-	-	-	30	17	9	4	46	34	23	15
	Exports	-	-	-	-	47	47	47	47	49	47	47	47
	Δ Farm Inc.	84	111	129	138	259	259	259	259	259	259	259	259
(B)	Fin. Ben.[a]	40	53	61	65	42	55	65	69	26	38	49	58
	Fin. Ben.[b]	48	64	75	80	48	64	75	80	29	43	56	67
	Fin. Ben.[c]	40	52	60	64	41	53	61	65	26	37	47	55
	Fin. Ben.[d]	39	51	60	64	39	51	60	64	24	35	45	54
	Imports	-	-	-	-	23	12	5	2	38	26	17	10
	Exports	-	-	-	-	43	43	43	43	44	43	43	43
	Δ Farm Inc.	87	111	122	127	235	235	235	235	235	235	235	235
(C)	Fin. Ben.[a]	41	52	58	60	43	55	61	64	28	40	50	57
	Fin. Ben.[b]	51	65	72	75	51	65	72	75	31	46	59	68
	Fin. Ben.[c]	41	52	57	60	42	52	58	60	27	38	48	54
	Fin. Ben.[d]	41	52	57	59	41	52	57	59	26	37	47	54
	Imports	-	-	-	-	16	7	3	1	31	19	11	6
	Exports	-	-	-	-	39	39	39	39	40	39	39	39
	Δ Farm Inc.	89	107	113	116	212	212	212	212	212	212	212	212
(D)	Fin. Ben.[a]	42	50	54	55	45	54	57	58	30	41	50	55
	Fin. Ben.[b]	53	64	68	70	53	64	68	70	34	49	60	66
	Fin. Ben.[c]	42	51	54	55	42	51	54	55	29	40	47	52
	Fin. Ben.[d]	42	51	54	55	42	51	54	55	28	39	47	52

[a]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[b]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D7. Expected present values of storage benefits for rice (Rs. million) stabilization around $\bar{P}$=Rs. 800 per ton[a]

	Scheme-A				Scheme-B				Scheme-C			
	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.5	M_1=3.0 M_2=1.0	M_1=4.0 M_2=1.5	M_1=5.0 M_2=2.0
Initial Inv.	-1,900	-2,850	-3,800	-4,750	-1,900	-2,850	-3,800	-4,750	-1,900	-2,850	-3,800	-4,750
Imports	–	–	–	–	-126	-28	-5	0	-250	-126	-60	-28
Exports	–	–	–	–	699	688	686	686	728	699	691	688
Δ Farm Inc.	-615	-701	-723	-728	109	109	109	109	109	109	109	109
(A) Fin. Ben.[b]	410	475	491	495	466	536	554	558	394	466	512	536
Fin. Ben.[c]	629	711	731	735	625	709	729	734	536	625	680	709
Fin. Ben.[d]	383	444	460	464	380	442	458	462	316	380	421	442
Fin. Ben.[e]	416	478	494	497	413	476	492	496	347	413	454	476
Imports	–	–	–	–	-18	-1	0	0	-44	-18	-6	-1
Exports	–	–	–	–	283	282	282	282	286	283	282	282
Δ Farm Inc.	-208	-314	-315	-315	31	31	31	31	31	31	31	31
(B) Fin. Ben.[b]	218	230	231	231	238	251	252	252	220	238	248	251
Fin. Ben.[c]	298	313	315	315	298	313	314	314	275	298	309	313
Fin. Ben.[d]	212	223	224	224	211	223	224	224	194	211	220	223
Fin. Ben.[e]	219	230	231	231	218	231	231	231	201	218	227	230
Imports	–	–	–	–	-1	0	0	0	-6	-1	0	0
Exports	–	–	–	–	85	85	85	85	85	85	85	85
Δ Farm Inc.	-105	-106	-106	-106	-2	-2	-2	-2	-2	-2	-2	-2
(C) Fin. Ben.[b]	80	81	81	81	86	87	87	87	82	86	87	87
Fin. Ben.[c]	105	106	106	106	105	106	106	106	100	105	106	106
Fin. Ben.[d]	79	80	80	80	79	80	80	80	75	79	80	80
Fin. Ben.[e]	80	81	81	81	80	81	81	81	76	80	81	81
Imports	–	–	–	–	0	0	0	0	Neg.	0	0	0
Exports	–	–	–	–	19	19	19	19	19	19	19	19
Δ Farm Inc.	-23	-23	-23	-23	–	0	0	0	0	0	0	0
(D) Fin. Ben.[b]	18	18	18	18	19	19	19	19	19	19	19	19
Fin. Ben.[c]	23	23	23	23	23	23	23	23	23	23	23	23
Fin. Ben.[d]	18	18	18	18	18	18	18	18	18	18	18	18
Fin. Ben.[e]	18	18	18	18	18	18	18	18	18	18	18	18

[a]Storage rules aimed at limiting price fluctuations at 2,3,4, and 5 percent of the desired mean price $\bar{P}$=Rs. 800 per ton are denoted by (A), (B), (C), and (D), respectively. For standard deviations of the estimates, see Appendix Table D8.

[b]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[e]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D8. Standard deviations of the estimates given in Appendix Table D7 (Rs. million)

	Scheme-A				Scheme-B				Scheme-C			
	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.5	M_1=3.0 M_2=1.0	M_1=4.0 M_2=1.5	M_1=5.0 M_2=2.0
Imports	-	-	-	-	14	6	2	Neg.	20	14	10	6
Exports	-	-	-	-	30	30	30	30	31	30	30	30
Δ Farm Inc.	22	27	29	30	50	50	50	50	50	50	50	50
(A) Fin. Ben.[a]	17	21	22	23	18	22	24	24	15	18	21	22
Fin. Ben.[b]	21	26	28	29	21	26	28	29	17	21	24	26
Fin. Ben.[c]	17	20	22	22	17	20	22	22	14	17	19	20
Fin. Ben.[d]	17	20	22	22	17	20	22	22	14	17	19	20
Imports	-	-	-	-	5	1	Neg.	0	8	5	2	1
Exports	-	-	-	-	20	20	20	20	21	20	20	20
Δ Farm Inc.	19	21	21	21	33	33	33	33	33	33	33	33
(B) Fin. Ben.[a]	15	16	16	16	16	17	17	17	14	16	17	17
Fin. Ben.[b]	19	20	20	20	19	20	20	20	16	19	20	20
Fin. Ben.[c]	14	16	16	16	14	16	16	16	13	14	15	16
Fin. Ben.[d]	14	16	16	16	14	16	16	16	13	14	15	16
Imports	-	-	-	-	1	0	0	0	2	1	0	0
Exports	-	-	-	-	11	11	11	11	11	11	11	11
Δ Farm Inc.	12	12	12	12	18	18	18	18	18	18	18	18
(C) Fin. Ben.[a]	9	10	10	10	10	10	10	10	9	10	10	10
Fin. Ben.[b]	12	12	12	12	12	12	12	12	11	12	12	12
Fin. Ben.[c]	9	9	9	9	9	9	9	9	9	9	9	9
Fin. Ben.[d]	9	10	10	10	9	10	10	10	9	9	10	10
Imports	-	-	-	-	0	0	0	0	0	0	0	0
Exports	-	-	-	-	5	5	5	5	5	5	5	5
Δ Farm Inc.	6	6	6	6	9	9	9	9	9	9	9	9
(D) Fin. Ben.[a]	5	5	5	5	5	5	5	5	5	5	5	5
Fin. Ben.[b]	6	6	6	6	6	6	6	6	6	6	6	6
Fin. Ben.[c]	5	5	5	5	5	5	5	5	4	5	5	5
Fin. Ben.[d]	5	5	5	5	5	5	5	5	4	5	5	5

[a] Financial benefits corresponding to the four sets of values $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[b] Financial benefits corresponding to the four sets of values $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c] Financial benefits corresponding to the four sets of values $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d] Financial benefits corresponding to the four sets of values $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D9. Expected present values of storage benefits for rice (Rs. million): stabilization around $\bar{P}$=Rs. 900 per ton[a]

	Scheme-A				Scheme-B				Scheme-C			
	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.5	M_1=3.0 M_2=1.0	M_1=4.0 M_2=1.5	M_1=5.0 M_2=2.0
Initial Inv.	-2,100	-3,150	-4,200	-5,250	-2,100	-3,150	-4,200	-5,250	-2,100	-3,150	-4,200	-5,250
Imports	-	-	-	-	-126	-28	-5	Neg.	-250	-126	-60	-28
Exports	-	-	-	-	699	688	686	686	728	699	699	688
Δ Farm Inc.	-692	-789	-813	-819	122	122	122	122	122	122	122	122
(A) Fin. Ben.[b]	479	553	572	576	536	614	634	639	453	536	587	614
Fin. Ben.[c]	695	785	808	813	691	783	806	811	592	691	751	783
Fin. Ben.[d]	449	519	537	541	446	517	535	539	372	446	492	517
Fin. Ben.[e]	482	553	570	575	478	550	568	573	403	478	525	550
Imports	-	-	-	-	-18	-1	0	0	-44	-18	-6	-1
Exports	-	-	-	-	283	282	282	282	286	283	282	282
Δ Farm Inc.	-335	-353	-354	-354	34	34	34	34	34	34	34	34
(B) Fin. Ben.[b]	250	264	265	265	270	285	286	286	249	270	281	285
Fin. Ben.[c]	329	346	348	348	329	346	347	347	304	329	341	346
Fin. Ben.[d]	243	256	257	257	242	256	257	257	223	242	252	256
Fin. Ben.[e]	250	263	264	264	249	263	264	264	230	249	259	263
Imports	-	-	-	-	-1	0	0	0	-6	-1	0	0
Exports	-	-	-	-	85	85	85	85	85	85	85	85
Δ Farm Inc.	-118	-120	-120	-120	-2	-2	-2	-2	-2	-2	-2	-2
(C) Fin. Ben.[b]	91	92	92	92	97	98	98	98	93	97	98	98
Fin. Ben.[c]	116	117	117	117	116	117	117	117	111	116	117	117
Fin. Ben.[d]	90	91	91	91	90	91	91	91	86	90	91	91
Fin. Ben.[e]	91	92	92	92	91	92	92	92	87	91	92	92
Imports	-	-	-	-	0	0	0	0	0	0	0	0
Exports	-	-	-	-	19	19	19	19	19	19	19	19
Δ Farm Inc.	-26	-26	-26	-26	0	0	0	0	0	0	0	0
(D) Fin. Ben.[b]	21	21	21	21	22	22	22	22	21	22	22	22
Fin. Ben.[c]	26	26	26	26	26	26	26	26	25	26	26	26
Fin. Ben.[d]	21	21	21	21	21	21	21	21	20	21	21	21
Fin. Ben.[e]	21	21	21	21	21	21	21	21	20	21	21	21

[a] Storage rules aimed at limiting price of fluctuations at 2, 3, 4 and 5 percent of the desired mean price $\bar{P}$=Rs. 900 per ton are denoted by (A), (B), (C), and (D) respectively. For standard deviations of the estimates, see Appendix Table D10.

[b] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[e] Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D10. Standard deviations of the estimates given in Appendix Table D9 (Rs. million)

	Scheme-A				Scheme-B				Scheme-C			
	$M_1=2.0$ $M_2=0.0$	$M_1=3.0$ $M_2=0.0$	$M_1=4.0$ $M_2=0.0$	$M_1=5.0$ $M_2=0.0$	$M_1=2.0$ $M_2=0.0$	$M_1=3.0$ $M_2=0.0$	$M_1=4.0$ $M_2=0.0$	$M_1=5.0$ $M_2=0.0$	$M_1=2.0$ $M_2=0.5$	$M_1=3.0$ $M_2=1.0$	$M_1=4.0$ $M_2=1.5$	$M_1=5.0$ $M_2=2.0$
Imports	–	–	–	–	14	6	2	Neg.	20	14	10	6
Exports	–	–	–	–	30	30	30	30	31	30	30	30
Δ Farm Inc.	25	31	33	34	56	56	56	56	56	56	56	56
(A) Fin. Ben.[a]	19	24	25	26	20	25	27	27	17	20	23	25
Fin. Ben.[b]	23	29	31	32	23	29	31	32	19	23	27	29
Fin. Ben.[c]	19	23	24	25	19	23	24	25	16	19	21	23
Fin. Ben.[d]	19	23	24	25	19	23	24	25	15	19	21	23
Imports	–	–	–	–	5	1	0	0	8	5	2	1
Exports	–	–	–	–	20	20	20	20	21	20	20	20
Δ Farm Inc.	22	24	24	24	38	38	38	38	38	38	38	38
(B) Fin. Ben.[a]	17	18	18	18	18	19	19	19	16	18	19	19
Fin. Ben.[b]	21	22	23	23	21	22	23	23	18	21	22	22
Fin. Ben.[c]	16	18	18	18	16	18	18	18	14	16	17	18
Fin. Ben.[d]	16	18	18	18	16	18	18	18	14	16	17	18
Imports	–	–	–	–	1	0	0	0	2	1	0	0
Exports	–	–	–	–	11	11	11	11	11	11	11	11
Δ Farm Inc.	14	14	14	14	20	20	20	20	20	20	20	20
(C) Fin. Ben.[a]	11	11	11	11	11	12	12	12	11	11	12	12
Fin. Ben.[b]	13	14	14	14	13	14	14	14	12	13	14	14
Fin. Ben.[c]	11	11	11	11	11	11	11	11	10	11	11	11
Fin. Ben.[d]	11	11	11	11	11	11	11	11	10	11	11	11
Imports	–	–	–	–	0	0	0	0	0	0	0	0
Exports	–	–	–	–	5	5	5	5	5	5	5	5
Δ Farm Inc.	7	7	7	7	10	10	10	10	10	10	10	10
(D) Fin. Ben.[a]	5	5	5	5	5	5	5	5	5	5	5	5
Fin. Ben.[b]	6	6	6	6	6	6	6	6	6	6	6	6
Fin. Ben.[c]	5	5	5	5	5	5	5	5	5	5	5	5
Fin. Ben.[d]	5	5	5	5	5	5	5	5	5	5	5	5

[a]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[b]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[c]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

[d]Financial benefits corresponding to the four sets of values of $P_{it}+C_1$ and $P_{it}+C_2$ given in Table 19.

Table D11. Standard deviations of the estimates given in Table 20 for cereals storage program

	Scheme-A				Scheme-B				Scheme-C			
	M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2= 0.0	M_1=5.0 M_2=0.0	M_1=7.0 M_2=0.0	M_1=9.0 M_2=0.0	M_1=11.0 M_2= 0.0	M_1=5.0 M_2=2.0	M_1=7.0 M_2=2.5	M_1=9.0 M_2=3.0	M_1=11.0 M_2= 3.5
Price Dev.*[a]	.036	.035	.035	.035	.004	.004	.004	.004	.004	.004	.004	.004
Farm Income Dev.**[a]	.022	.024	.024	.024	.019	.019	.019	.019	.019	.019	.019	.019
(A) Ave. Op. Stock[b]	.035	.049	.058	.062	.035	.049	.058	.062	.020	.031	.042	.052
Total Imports[b]	-	-	-	-	.104	.074	.046	.026	.136	.112	.088	.066
Total Exports[b]	-	-	-	-	.104	.136	.136	.136	.154	.141	.137	.136
Price Dev.*[a]	.033	.032	.032	.032	.008	.008	.008	.008	.008	.008	.008	.008
Farm Income Dev.**[a]	.022	.023	.023	.023	.013	.013	.013	.013	.013	.013	.013	.013
(B) Ave. Op. Stock[b]	.039	.051	.057	.059	.039	.051	.057	.059	.022	.035	.046	.053
Total Imports[b]	-	-	-	-	.082	.053	.030	.015	.115	.090	.067	.045
Total Exports[b]	-	-	-	-	.124	.123	.123	.123	.134	.125	.123	.123
Price Dev.*[a]	.032	.031	.030	.030	.012	.012	.012	.012	.012	.012	.012	.012
Farm Income Dev.**[a]	.022	.022	.022	.022	.008	.008	.008	.008	.008	.008	.008	.008
(C) Ave. Op. Stock[b]	.042	.051	.055	.056	.042	.051	.055	.056	.026	.038	.047	.052
Total Imports[b]	-	-	-	-	.062	.036	.018	.008	.095	.070	.048	.030
Total Exports[b]	-	-	-	-	.113	.113	.113	.113	.119	.114	.113	.113
Price Dev.*[a]	.032	.031	.031	.030	.016	.016	.016	.016	.016	.016	.016	.016
Farm Income Dev.**[a]	.021	.021	.021	.021	.008	.008	.008	.008	.008	.008	.008	.008
(D) Ave. Op. Stock[b]	.042	.049	.051	.052	.042	.049	.051	.052	.028	.040	.046	.050
Total Imports[b]	-	-	-	-	.044	.023	.010	.002	.075	.051	.032	.019
Total Exports[b]	-	-	-	-	.103	.102	.102	.102	.106	.103	.102	.102

[a]Expressed as percent.

[b]Expressed in million tons.

*The value without storage is 0.051.

**The value without storage is 0.029.

Table D12. Standard deviations of the estimates given in Table 21 for rice storage program

		Scheme-A				Scheme-B				Scheme-C			
		M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.0	M_1=3.0 M_2=0.0	M_1=4.0 M_2=0.0	M_1=5.0 M_2=0.0	M_1=2.0 M_2=0.5	M_1=3.0 M_2=1.0	M_1=4.0 M_2=1.5	M_1=5.0 M_2=2.0
	Price Dev.*[a]	.011	.010	.010	.010	.007	.007	.007	.007	.007	.007	.007	.007
	Farm Income Dev.**[a]	.004	.005	.006	.006	.007	.007	.007	.007	.007	.007	.007	.007
(A)	Ave. Op. Stock[b]	.018	.021	.022	.023	.018	.021	.022	.023	.015	.018	.020	.021
	Total Imports[b]	–	–	–	–	.021	.010	.004	.001	.029	.021	.015	.010
	Total Exports[b]	–	–	–	–	.045	.044	.044	.044	.046	.045	.044	.043
	Price Dev.*[a]	.014	.013	.013	.013	.011	.011	.011	.011	.011	.011	.011	.011
	Farm Income Dev.**[a]	.004	.004	.004	.004	.003	.003	.003	.003	.003	.003	.003	.003
(B)	Ave. Op. Stock[b]	.015	.016	.016	.016	.015	.016	.016	.016	.013	.015	.016	.016
	Total Imports[b]	–	–	–	–	.006	.001	–	–	.011	.006	.003	.001
	Total Exports[b]	–	–	–	–	.029	.028	.028	.028	.029	.029	.028	.028
	Price Dev.*[a]	.015	.015	.015	.015	.014	.014	.014	.014	.014	.014	.014	.014
	Farm Income Dev.**[a]	.004	.004	.004	.004	.003	.003	.003	.003	.003	.003	.003	.003
(C)	Ave. Op. Stock[b]	.009	.010	.010	.010	.009	.010	.010	.010	.009	.010	.010	.010
	Total Imports[b]	–	–	–	–	.001	.000	.000	.000	.003	.010	.000	.000
	Total Exports[b]	–	–	–	–	.014	.014	.014	.014	.014	.014	.014	.014
	Price Dev.*[a]	.017	.017	.017	.017	.016	.016	.016	.016	.016	.016	.016	.016
	Farm Income Dev.**[a]	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004
(D)	Ave. Op. Stock[b]	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
	Total Imports[b]	–	–	–	–	.000	.000	.000	.000	.000	.000	.000	.000
	Total Exports[b]	–	–	–	–	.007	.007	.007	.007	.007	.007	.007	.007

[a]Expressed as percent.

[b]Expressed in million tons.

*The value without storage is 0.017.

**The value without storage is 0.004.

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