# ESTIMATION OF FARM SUPPLY RESPONSE AND ACREAGE ALLOCATION
## A Case Study of Indian Agriculture

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## SUMMARY

Some of the most important decisions in agricultural production, such as what crops to grow and on how much land, have to be taken in an uncertain environment of future rain, yield and prices. This paper aims at modelling the land allocation decisions of the Indian farmers as an important first step in developing a model for Indian Agricultural Policy. The approach adopted is consistent with the basic premise that farmers behave rationally and that rational farmers react in a way that maximizes their utility in the contexts of opportunities, uncertainties and risks as perceived by them.

After a brief review of the available approaches towards estimating the farm supply response, a summary of a few important studies in this connection was provided which are essentially based on the traditional Nerlovian model.

Nerlovian model, based on adaptive expectations and adjustment schemes is quite general and is applicable for the study of acreage response even for developing economies like India. However, there seems to be a serious misspecification involved in this model as far as the formulation of the price expectation function is concerned. Nervolian specification does not separate the actually realized prices in the past into "stationary" (or expected) and random components, and attaches the same weights to the two components for predicting expected prices.

This paper deviates from the traditional Nerlovian model on two counts mainly:

1. Acreage response to different crops was estimated using expected revenue instead of expected price as a proxy for expected profits.

2. First, an appropriate revenue (or price as the case may be) expectation function was formulated for each crop by clearly identifying the "stationary" and random components involved in the past values of the variable, and attaching suitable weights to these components for prediction purposes. An Auto Regressive Integrated Moving Average (ARIMA) type model was postulated towards this purpose and Box-Jenkins methodology was made use of in estimating these functions.

Almost all the crops grown in India were considered in our study. Based on sowing and harvesting periods and also some important data, an overall substitution pattern among the crops at all-India level was drawn up. This pattern permits classification of the crops into ten groups where the crops in different groups are usually grown in different soils and/or different seasons. The essential data for estimating the acreage response consists of area, production, yield, irrigation, prices and rainfall.

The revenue expectation functions for different crops estimated as mentioned earlier, were later plugged in the Nerlovian model and the acreage response equations were estimated.

Later, an area-allocation scheme was formulated so that the individually estimated areas of different crops would add up to the exogenously specified total gross cropped area in the country.

Finally, the estimated equations were all subjected to a validation exercise to judge the performance of the model; particularly its ability to predict the turning points.

CONTENTS

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## THE PROBLEM AND ITS IMPORTANCE

Any analysis of agricultural policy needs to deal with the problem of affecting the supply of agricultural outputs. Not only the levels of output but also the composition is relevant for the purposes of policy. Agricultural supply, however, is the outcome of the decisions of a large number of farmers. How do farmers decide what and how much to produce? What affects their decisions? What are the policy instruments that affect these decisions? It is essential to understand these questions if a successful policy is to be devised.

An important characteristic of agricultural production is the time lag involved in it. Outputs are obtained months after planting operations are begun. Farmers have comparatively little control after planting has been done to affect the output.

The most important decisions are what crops to grow and on how much land. These decisions have to be taken in an uncertain environment of future rain and harvest prices. How do farmers form their expectations about future prices and how do these expectations affect their crucial decisions on land allocation?

Our purpose in this paper is to investigate this set of issues for the Indian farmers. We wish to model the land allocation decisions of the Indian farmers as an important first step in developing a model for Indian Agricultural Policy. The framework of the full model, a computable general equilibrium type one, was described by Parikh K.S. (1977).

We start with the basic premise that farmers behave rationally, and that rational farmers should react in a way that maximizes their utility within the contexts of opportunities, uncertainties and risks as perceived by them. Our approach is consistent with this premise. We estimate our model econometrically using Indian data from 1950 to 1974. The model essentially states that farmers' desired allocation of their land among competing crops depends on rainfall and "expected" relative revenue, of different crops. Moreover, there are constraints which may restrict the farmers in the rate at which they can adopt to a new desired cropping pattern.

We have preferred to use expected revenue in place of the expected prices as not only expected revenue is theoretically more satisfactory (farmers must observe that in good years prices fall) but that a lot of uncertainty is also associated with yields. Expected revenue is used as a proxy for expected profits as for farmers who operate with a fixed amount of total available inputs, an amount which is less than profit maximising input level, maximising profits and maximising revenue give the same results.

The model developed is suitable for use as a part of a year by year simulation type price endogenous computable general equilibrium model referred to above. A validation exercise is also carried out to test the performance in simulation of the area allocation system developed.

The rest of the paper is organized as follows: In section 2, we discuss certain methodological issues. A review of literature follows in section 3. In section 4, we describe our experience with the estimation of Nerlovian model on acreage responses, and then the estimation of crop-revenue expectation functions based on Box-Jenkins methodology, and the modified acreage response model. Section 5, deals with the area allocation model. In section 6, we describe the validation exercises. A summary and conclusions will follow in section 7.

## POSSIBLE APPROACHES TO MODELLING SUPPLY RESPONSES

The modelling approach to supply responses that we have followed is a two stage one. In stage one which is described in the present paper, farmers allocate their land to different crops. This is followed by stage two (which will be described in a forthcoming paper) in which given the areas, farmers allocate the inputs and non-land factors to different crops to maximise profits. The first stage model is an econometric one and the second stage model is a programming one.

The question is why follow such a two-stage procedure instead of one in which all allocation decisions of land as well as of other factors and inputs are simultaneously made?

For the one stage procedure one can consider two broad approaches: one is to develop a programming model in which area allocation is internal and the other is to have an econometric estimate of the output levels themselves as supply functions.

Both these alternatives have certain limitations. A programming approach leads to a corner solution in which land gets allocated to one crop, unless the area allocations are constrained explicitly or through production functions in which there are diminishing returns to area devoted to one crop. It is sometimes suggested that explicit constraints on areas prescribed exogenously are acceptable or even desirable particularly when there is a large amount of self consumption by the farmers in the economy. Essentially however, the argument boils down to an implicit assumption that farmers' area allocation decisions are so complex as to be non-modellable or that there is so little choice available to farmers to allocate land to different crops that the arbitrariness of explicit area constraints is tolerable. This however, is questionable and needs to be tested empirically. Even farmers growing food largely for self consumption should not be insensitive to changing prices and profitabilities. Self consumption can be viewed as the farmer selling to and buying from himself and thereby the trade margin on that amount accrues to the farmer himself. Once this fact is taken into account, a rational farmer should wish to maximize expected profits, including margin on trade for self consumption. Similarly, the perverse relationship of marketable surplus to prices (marketable surplus going down as prices rise)[1] can be also consistent with conventional economic theory. Higher prices for his products make the farmer richer so that he might want to consume more of his own product. These arguments would suggest that one should not rule out attempts to model farmers' land allocation decisions before opting for a procedure of arbitrary constraints.

The other alternative way of avoiding corner solutions in a programming model is to introduce diminishing returns to size of area devoted to a crop. Empirical estimates of such production functions are not easy to make and are not generally available. Moreover, the data required to make such estimates are also not plentiful. Thus it is a difficult procedure to follow.

An estimation of an econometric output supply function is unsatisfactory for a policy simulation model. Since only the final outcome of a number of decisions would get estimated, it would provide less flexibility in changing certain parameters in the model. For example, the impact of new high yielding varieties may be hard to assess in such a framework. In the two stage procedure we have followed, introduction of a new variety would only affect the expectations but not the allocation mechanism. Moreover, the two stage procedure also generates information on the technology selected which is important for determination of income generation in the model.

## A BRIEF REVIEW OF LITERATURE ON SUPPLY RESPONSES

Most of the empirical research in the area of estimating farmers' acreage response is based on either direct application or minor modification or further extension of the celebrated work of Marc Nerlove (1958). Nerlove distinguishes three types of output changes: "(1) in response to changes in current prices which do not affect the level of expected future prices, (2) in immediate response to a change in the level of expected future prices, and (3) in response to a change in the expected and actual level of prices after sufficient time has elapsed to make full adjustment possible". Of these, output changes of the first type may be very much limited because a sudden change in the output based on sudden changes in the input/output prices may be difficult and also because if the change (increase or decrease) is only a short-run phenomenon then such quick and frequent output changes may turn out to be quite costly. Hence such output changes (i.e., of **the** first type) are ignored. That leaves out the essential ideas of the Nerlovian model that 1) farmers, over time, keep adjusting their output towards a desired (or equilibrium) level of output in the long-run based on the expected future prices, 2) current prices affect the output only to the extent that current prices alter the expected future prices, and 3) short-run adjustments in the output, which are made keeping the longterm desired level of output in mind, may not fully reach the longterm desired level since there may be constraints on the speed of acreage adjustment. His model is as follows:

$$X_t^* = a_o + a_1 P_t^* + a_2 Z_t + U_t \quad , \qquad (3.1)$$

$$P_t^* = \beta P_{t-1} + (1 - \beta) P_{t-1}^* \quad , \quad 0 < \beta \leq 1 \quad , \qquad (3.2)$$

$$X_t = (1 - \gamma) X_{t-1} + \gamma X_t^* \quad , \quad 0 < \gamma \leq 1 \quad , \qquad (3.3)$$

where

$X_t^*$ is the longrun desired (equilibrium) acreage of the crop in period t,

$X_t$ is the actual acreage,

$P_t^*$ is the expected "normal" price,

$P_t$ is the actual price,

$Z_t$ is any other relevant variable (say, rainfall),

$U_t$ is a random residual,

$\beta$ is the price expectation coefficient,

$\gamma$ is the acreage adjustment coefficeint.

Equation (3.2) implies, given that $0 < \beta \leq 1$, the current expected price $P_t^*$ falls somewhere in between the last year's actual price $P_{t-1}$ and the last year's expected price, $P_{t-1}^*$. That is to say, the current year's expected price is revised in proportion to the difference between the actual and expected prices during the previous year. If $\beta = 0$, the expectation pattern is independent of the actual prices, and also there exists only one expected price for all time periods. If $\beta = 1$, current year's expected price is always equal to the last year's actual price.

The restriction $0 < \beta \leq 1$ is an essential one. The value of $\beta$ indicates the nature of the movement of price-expectations over time as observations of actual prices are made. If $\beta$ is either less than zero or greater than one, the price expectation pattern represents a movement away from the actual price movement especially in a stationary state when the price $P_t$ = constant for all time periods. This is irrational behaviour as one would naturally expect that as the same price repeats year after year the farmers expect the price correctly. It may be noted that some researchers[2] have presented empirical results which do not satisfy the condition $0 < \beta \leq 1$.

Equation (3.3) also implies a similar process of acreage adjustment. Farmers adjust their acreage in proportion to the difference between the desired or longrun equilibrium level and the actual acreage level during the previous period.

Again a meaningful interpretation requires that $0 < \gamma \leq 1$; for $\gamma < 0$ implies that a farmer allocates less area in time 't' than that in time (t - 1) while in fact, he desires to have more (assuming that $X_t^* > X_{t-1}$), and $\gamma > 1$ implies over-adjustment.

As can be observed from (3.1), (3.2) and (3.3) the longrun equilibrium and expected variables, are not observable. Hence for estimation purposes, a reduced form containing only observable variables could be written (after some algebraic manipulation) as follows:

$$(3.4)\quad X_t = a_o\beta\gamma + a_1\beta\gamma P_{t-1} + (1 - \beta + 1 - \gamma)X_{t-1} - (1 - \beta) \times (1 - \gamma)X_{t-2} + a_2\gamma Z_t - a_2(1 - \beta)\gamma Z_{t-1} + \gamma[U_t - (1 - \beta)U_{t-1}] \quad .$$

Behind the reduced form (3.4) are the hypotheses and assumptions as described above. It might be possible to arrive at the same reduced form as in (3.4) probably under a different set of hypotheses and assumptions. Unless the structural parameters are identified and are found to be satisfactory, a good fit for the reduced form is hard to interpret.

Fisher and Temin (1970) give an example of a reduced form equation obtainable by different sets of hypotheses. They write an equation as follows (notation changed and trend variable 't' added):

$$(3.5)\quad X_t = a_1 + a_2P_{t-1} + a_3t + a_4X_{t-1} + U_t \quad ,$$

and say that (3.5) may be arrived at in (at least) three different ways: 1) (3.5) can be modified and rewritten to express $X_t$ as a function of past prices, which then means that current acreage is related to past observed prices, 2) farmers conceive of a desired level of acreage, say $X_t^*$ knowing $P_{t-1}$; but somehow are unable to achieve that level.

Now, if

$$X_t^* = a_1^* + a_2^* P_{t-1} + a_3^* t + U_t^* \quad ,$$

$$X_t - X_{t-1} = \mu(X_t^* - X_t) + W_t \quad , \qquad (0 < \mu \leq 1) \quad ,$$

then after substitution (3.5) may be arrived at; 3) i.e., whatever may be the adjustment ability, farmers take decisions based on expected price which is formed by observing the actual prices. If

$$X_t = a^* + a_2^* P_{t-1}^* + a_3^* t + V_t \quad ,$$

$$P_t^* - P_{t-1}^* = \mu(P_t - P_{t-1}^*) \quad , \qquad (0 < \mu \leq 1) \quad ,$$

then again from these two relations $X_t$ can be expressed as a function of past prices.

In the cases above, these hypotheses lead to observationally indistinguishable reduced forms. The Nerlovian case corresponds to a situation where the latter two hypotheses were made both together.

There are some estimation problems associated with (3.4), which need to be mentioned briefly here. Suppose, for a while, that there is no $Z_t$ variable in equation (3.1) of the system. Then the reduced form becomes

$$(3.6) \quad X_t = a_o\beta\gamma + a_1\beta\gamma P_{t-1} + (1 - \beta + 1 - \gamma)X_{t-1} - (1 - \beta) \times (1 - \gamma)X_{t-2} + \gamma[U_t - (1 - \beta)U_{t-1}] \quad .$$

Then $\beta \cdot \gamma$ (i.e., the product of $\beta$ and $\gamma$) can be obtained from the quadratic equation formed out of the coefficients of $X_{t-1}$ and $X_{t-2}$ of (3.6) but not $\beta$ and $\gamma$ separately. Using the estimate of $(\beta \cdot \gamma)$, however, an estimate of '$a_1$' can clearly be obtained.

Hence, even though the adjustment and expectation parameters $\beta$ and $\gamma$ are not identified separately the longrun elasticity with respect to expected price may still be known unambiguously.

This difficulty of parameter-identification cannot be overcome even by introducing another variable $Z_t$ into the system. As can be seen from (3.4) such an introduction yields separate, but not unique, estimates of $\beta$ and $\gamma$. However, by postulating suitable expectation pattern, one might be able to solve this difficulty. In the Nerlovian system, farmers have expectations only about the price-variable. Actually, farmers might have expectations about several other variables simultaneously, for example, yield, rainfall, etc. Their area-allocation decisions would follow from all these expectations. Suppose $Z_t$ is one such variable with its expected value as $Z_t^*$. Now, using the expectation-form of $Z_t^*$ it might be possible to resolve the parameter-identification difficulty. This depends upon the exact functional-relationships of the expectation variables. Suppose that,

$$Z_t^* = \alpha_1 Z_{t-1} + \alpha_2 Z_{t-2}$$

with

$$\alpha_2 = 1 - \alpha_1 \quad .$$

Then the corresponding reduced form would be

$$\begin{aligned} X_t = a_o\beta\gamma + a_1\beta\gamma P_{t-1} + (1 - \beta + 1 - \gamma)X_{t-2} + a_2\gamma\alpha_1 Z_{t-1} \\ + a_2\gamma(\alpha_2 - (1 - \beta)\alpha_1)Z_{t-2} - (1 - \beta)\alpha_2 a_2\gamma Z_{t-3} \\ + \gamma[U_t - (1 - \beta)U_{t-1}] \quad . \end{aligned}$$

In this case it can be shown that there is no parameter-identification problem. However, it must be noted that such an introduction of a new variable into the system and the corresponding expectation function formulation must be justifiable.

Nerlove's basic model has inspired a lot of empirical research in a number of countries including India during the last one and a half decades in the area of estimating the acreage response of farmers to price-movements. We shall now briefly review the existing literature in this area in regard to any modifications and further extensions brought over the Nerlove model. Occasionally we might make some comments about the estimation problems involved also.

One of the earliest attempts to apply Nerlove-type approach to Indian data was by Rajkrishna (1963). His model, simply an area adjustment supply model, includes irrigation, rainfall, relative price and yield variables. He does not distinguish between actual and expected prices which implies farmers have full knowledge of what the prices are going to be[3]. Dharam Narain's study (1965) on the impact of price movements on areas under selected Indian crops is not based on Nerlove-type approach but on graphical analysis. Since it is not based on econometric analysis the usual estimation problems disappear but that makes comparison of his results and approach with those of other researchers difficult[4].

Cummings (1975) writes the reduced form (3.4) in the following way:

$$(3.7)\quad [A_t - (1-\beta)A_{t-1}] = a_o\beta\gamma + a_1\beta\gamma P_{t-1} + (1-\gamma)[A_{t-1} - (1-\beta) \times A_{t-2}] + a_2\gamma[Z_t - (1-\beta)Z_{t-1}] + \gamma[U_t - (1-\beta)U_{t-1}] \quad .$$

He estimates equation (3.7) for a range of specified values of $\beta$ and selects that value of $\beta$ "for which the regression error sum of squares is minimized". The following may be noted:

1. According to him, the price-expectation coefficient "can be reasonably assumed to fall within the range of zero to two". No justification is provided for assuming $\beta$ to be greater than one.

2. To take care of auto-correlation, he employs Cochrane-Orcutt technique which uses a first-order auto-correlation scheme on the disturbance terms.

If equation (3.7) was estimated, it means that the following is assumed to be true:

$$(3.8)\quad [U_t - (1 - \beta)U_{t-1}] = \rho[U_{t-1} - (1 - \beta)U_{t-2}] + V_t$$

With usual assumptions on $V_t$ and $\rho$, equation (3.8) implies a second-order scheme of auto-disturbance for $U_t$ which is the basic disturbance term in equation (3.1) of the model. He gives explanation for neither the second-order auto-correlation scheme of $U_t$ nor the first-order one as is shown in (3.8).

Madhavan's study (1972) pays an explicit attention towards deriving the very first equation (3.1) of the Nerlovian type scheme. He formulates a Lagrangean to maximise farmers' net income:

$$J = \sum_i p_i Y_i - \mu H(Y_1, \ldots, Y_m) \quad ,$$

where $Y_i$ is the production function for i-th crop and H is the same for the farm as a whole. Setting the partial derivates to be zero and imposing the marginality conditions

$$(3.9)\quad (\partial Y_i/\partial X_i^*)/(\partial Y_j/\partial X_j^*) = P_j^*/P_i^* \quad ,$$

he derives

$$(3.10)\quad \log X_i^* = a_o + a_1 \log (P_j^*/P_i^*) + a_2 \log Y_i^* + a_3 \log Y_j^*$$
$$+ a_4 \log X_j^* + U_i \quad ,$$

where $X_i^*$ = desired acreage of i-th crop, $X_j^*$ = desired acreage of j-th crop, and P* and Y* are the expected levels of price and yields.

This formulation is interesting as it is a consequence of maximizing behaviour. He also brings in the competing crops and the relative yields into consideration. However, when it comes to expectations, he only assumes current expectations to be last year's actual values.

The next step in this field of research was the incorporation of elements of risk and uncertainty into consideration. In "a case study of four major annual crops in Thailand 1937-1963" Behrmann (1968) attempts to capture the influences of variability of prices and yields on supply response functions. Along with many other variables (e.g. population and malaria death rate etc.) he brings in the standard deviation of the price and yield in the last three periods into analysis with an intention that the standard deviations would give an idea of farmers' reaction to risks. However, Nowshirvani (1971) points out that Behrmann's analysis was an empirical exercise without an explicit theoretical model. He further points out that Behrmann's procedure is somewhat unsatisfactory because "the Nerlovian price expectations model is inconsistent with a changing variance of the subjective probability distribution of prices".

He develops a theoretical model for farmers' decisions on land allocation in which uncertainties in prices and yields are accounted for. Farmers' decisions follow from maximization of expected utility. Under a set of specific assumptions about farmers' utility functions, Nowshirvani shows that incorporation of risk in the analysis of agricultural supply may show a negative area - price response. Also the natural variability of land has an effect on the magnitude of this response. As he says, "if the diversification of cropping is not dictated by the physical conditions of production but rather by the desire to reduce risk, stabilization schemes may sometimes be more effective policy instruments than price in bringing about area shifts among crops". He also observes that when prices and yield are negatively correlated, price stabilization leads to income destabilization which could also lead to reduction in the area devoted to that crop.

Nowshirvani does not distinguish between the prices received by farmers and prices paid by him for the same product. However, many of his conclusions would seem to be strengthened by this differentiation.

Two issues, often raised are:

1. What is the relevant variable for characterizing farm supply response: acreage or farm output?
2. Which price should one use: average, pre-sowing, post-harvest, or modal or any others?

   Nerlov, Rajkrishna, Dharam Narain, etc., all used "area" and there was not much disagreement about it.

However, when it came to prices, different prices have been used in different studies. Nerlov used a sort of average price, while Rajkrishna used post-harvest prices and so on. Rao and Jaikrishna were mainly concerned with this issue in two of their studies (1965, 1967) and attempted to see the impact of different prices on the acreage estimations. In all, they used 21 different combinations or sets of different prices in these two studies. It might be difficult to pass a strict rule in favour of or against using any particular set of prices as being the best in explaining supply responses.

Whatever prices one might use, Parikh (1972), questions the validity of the assumption generally made that farmers react mainly to prices. In a static framework, he argues, prices can be the major determinant of allocation of land. However, in a dynamic set-up there are often other factors such as technological changes which might equally influence allocation decisions. In the case of time-series analysis this becomes even important. Also he says, when one is dealing with individual crops rather than with aggregate agricultural production it is the relative profitability which determines the extent of substitution of one crop for another.

A. Parikh uses relative price as well as yield expectations (though not a combined relative revenue expectation) and in an essentially Nerlovian model estimates from the data of 1900 to 1939 the market responsiveness of Indian farmers for commercial crops.

In the above discussion we have briefly reviewed some of the important studies in the existing literature on the theoretical development of the Nerlovian model in the studies on the acreage responses especially in developing countries. From the point of view of estimation there are some points that need to be made:

1. A large number of such studies are based on time-series data. Unfortunately, quite a few of them do not make it clear whether they took care of auto-correlation or not. The exact form of auto-correlation in the ultimate reduced form depends on the assumptions made on the nature of the disturbance - terms involved in the original model, and sometimes the application of Cochrane-Orcutt technique may not be sufficient.
2. Some studies accepted the naive expectation model as far as the price-expectation functions are concerned (i.e., $P_t^* = P_{t-1}$). This is probably due to the problem of parameter-identification. In some studies $P_t^*$ is written as a distributed lag of past prices assuming that the lag is known.
3. Almost all the studies are concerned with the estimation with regard to an individual crop in isolation. This is alright if one is interested in 1) only the projection values of that crop and 2) verifying certain hypotheses with regard to only that or a related crop. But many a time these may not be the only cases. More often than not, the total gross cropped area in a country or region for particular time-period becomes known exogenously in advance, but not the precise cropping pattern. For example, in the limiting cases it becomes difficult to add more and more area to the country's cultivable land and hence the total cropped area becomes scarce. Then one already knows the total available cultivable land and the problem would be to allocate this land over different crops.

In this case the sum of individually estimated cropped areas should add up to the total available land. It is necessary, hence, to draw up an allocation scheme and carry out the estimations, so that the adding-up requirement is satisfied. Such an allocation scheme is important especially if an inter-sectoral study based on large-scale systems is being aimed at.

Towards the end of this paper we present one such allocation scheme. Before proceeding further let us mention a few points:

1. We believe prices cannot adequately explain the acreage responses, and it is the revenue relative to that of competing crops a more appropriate variable for most of the crops.
2. We first separately estimate the revenue expectation functions for each crop[5]. As we have time-series data we employ Box-Jenkins method in estimating these revenue expectation functions.
3. The crop revenue expectation functions estimated in 2. will be later plugged in, in estimating the Nerlovian equations required.

## 4 ESTIMATIONS

### 4.1 Indian Crops

Rice happens to be the most growng crop in India. It accounted for roughly 23% of the total gross cropped area in the country in 1974. Wheat over time gradually evolved to be the next important crop closely followed by jowar and then by bajra. Wheat's total gross cropped area is around 50% of that of rice. Other important crops are maize, gram, barley and ragi among the foodgrains and groundnut, rapeseed and mustard, sesamum and cotton among the nonfood crops. Sugarcane accounted for 1.6% of the total area in 1974.

Appendix 1 provides data on the substitutable crops for most of the states in India. Appendix 2 provides data on the sowing, harvesting and peak marketing seasons of principal crops in India. As can be observed, the inter-crop substitution pattern generally varies from state to state.

This is essentially due to nature of the soils in different states and also, at least to some extent, due to customs and habits of people. These factors are implicit behind the sowing and harvesting periods of different crops as shown in Appendix 2. To arrive at an all-India level substitution pattern for crops, the following considerations were taken into account:

-- main and competing crops in each state
-- relative importance of each crop at all-India level
-- relative importance of each state with regard to crop at all-India level
-- sowing and harvesting periods of different crops.

Based on these considerations an overall substitution pattern of crops for all-India level could be drawn as follows:

-- rice, ragi, jute, mesta and sugarcane,
-- wheat, gram, barley, and sugarcane,
-- jowar, bajra, maize, cotton, oilseeds and sugarcane,
-- groundnut, rapeseed and mustard, sesamum and other oilseeds, within oilseeds,
-- fruits, vegetables, condiments and spices,
-- rubber,
-- coffee,
-- tea,
-- tobacco.

Based on the above pattern, the crops were classified into the following groups as shown in table 4.1.

Table 4.1. List of the crops and groups in the system.
All groups ($A_G$ = total gross cropped area)

| Group (g)<br>Crop (i) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Rice | Wheat | Maize | Ground-nut | Fruit & Veg. | Rubber | Coffee | Tea | Sugar-cane | Tobacco |
| 2 | Ragi | Gram | Bajra | Sesa-mum | Condi-ments & Spices | | | | | |
| 3 | Jute | Barley | Jowar | Rape & Mustard | | | | | | |
| 4 | Mesta | | Cotton | | | | | | | |
| $Q_g$ | Resi-dual | Resi-dual | Resi-dual | Resi-dual | | | | | | |
| Group Total ($A_G$) = $\sum_i A_{ig} + Q_g$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ | $A_9$ | $A_{10}$ |

It may be noted that crops in different groups are usually grown in different soils and/or in different seasons. However, sugarcane is one crop which covers more than one season and when ratooned (i.e., sugarcane not planted but allowed to grow from the stem left in the ground after the first harvest), the crop can cover more than one year.

The following specific points may also be noted:

1. As can be noted from Appendix 1, sugarcane (group 9) competes with most of the crops in groups 1,2 and 3. However, sugarcane may not be the main competing crop for some of them. In our analysis, computation of relative revenue for each crop, as can be seen later, is done with respect to its two important competing crops only.

Nevertheless, to account for such speciality of sugarcane, an attempt was made to find out the affect of increasing the irrigation facilities for sugarcane (which might result in increasing the yield and hence revenue) on the acreage-response of each crop in groups 1,2 and 3.

2. Oilseeds (group 4) compete with maize, baira etc., (group 3), but since group 4 has a total area which is much smaller than the total area of group 3, the competition in the reverse direction may not be too dominant.
3. Except for those mentioned in 1. and 2., there are no other inter-group substitution possibilities at all-India level.
4. The residual components in the first 3 groups contain small millets and pulses. These however, do not greatly compete with the other crops in the respective groups.

4.2 Our Experience with Nerlovian Model

We began our estimation exercises by applying the Nerlovian model as such. The set of variables in our analysis is as follows:

$A_{igt}$, $P_{igt}$, $Y_{igt}$, $R_{igt}$ : Area, wholesale price index, yield/ha and rainfall index of i-th crop in group g in period t.

| | | |
|---|---|---|
| $t$ | : | refers to time period |
| $*$ | : | refers to desired or expectation values |
| $\Pi_{igt} = P_{igt} \cdot Y_{igt}$ | : | revenue of ith crop in group g |
| $\Pi_{k1 \cdot g \cdot t}$ and $\Pi_{k2 \cdot g \cdot t}$ | : | revenues of competing crops (k1 and k2) |
| $I_{gt}$ | : | total irrigated area of all crops in group g |
| $I_{Gt}$ | : | total irrigated area in the country |
| $I_{st}$ | : | irrigated area of sugarcane |

The model, first tried, had the following equations:

$$(4.2.1) \quad A^*_{igt} = a_o + a_1\Pi^*_{igt} + a_2R_{igt} + a_3\Pi^*_{k1gt} + a_4\Pi^*_{k2gt} + U_t \quad ,$$

$$(4.2.2) \quad \Pi^*_{igt} - \Pi^*_{i \cdot g(t-1)} = \beta(\Pi_{igt-1} - \Pi^*_{igt-1}) \quad ,$$

$$(4.2.3) \quad \Pi^*_{k1gt} - \Pi^*_{k1 \cdot g(t-1)} = \beta[\Pi_{k1gt-1} - \Pi^*_{k1gt-1}]$$

$$(4.2.4) \quad \Pi^*_{k2gt} - \Pi^*_{k2gt-1} = \beta[\Pi_{k2gt-1} - \Pi^*_{k2gt-1}]$$

$$(4.2.5) \quad A_{igt} - A_{igt-1} = \gamma[A^*_{igt} - A_{igt-1}] - U_t$$

which give a reduced form

$$\begin{aligned}(4.2.6) \quad [A_{igt} - (1-\beta)A_{igt-1}] = a_o\beta\gamma + a_1\beta\gamma\Pi_{igt-1} &+ (1-\gamma) \\ &\cdot [A_{igt-1} - A_{igt-2}(1-\beta)] \\ &+ a_2\gamma[R_{igt} - (1-\beta)R_{igt-1}] \\ &+ a_3\beta\gamma \cdot [\Pi_{k1gt-1}] \\ &+ a_4\beta\gamma[\Pi_{k2gt-1}] \\ &- [(U_t - \rho\gamma U_{t-1}) - (1-\beta) \\ &\cdot (U_{t-1} - \rho\gamma U_{t-2})] \quad .\end{aligned}$$

To start with, we assumed the price-expectation coefficient to be the same for main crops as well as competing crops. Another assumption that needs to be noted is the specification of the disturbance term which is primarily to facilitate application of readily available techniques to take care of auto-correlation. The assumption of the same price expectation coefficient for all the competing crops implies that the equations for these crops should be estimated simultaneously. This is what we had intended to do. Nonetheless, we did make separately an estimate for each crop to see how the model behaves. However, we ran into trouble. The estimation of the reduced form (4.2.6) of the equations (4.2.1 to 4.2.5) was carried out for a range of specified values of $\beta$. We scanned out the range $0 < \beta \leq 1$ and observed the highest R-bar square. We were somewhat disappointed by our results. We observed that the highest R-bar square was always associated with $\beta = 1$ almost in all crops. The values of R-bar square were of course highly attractive in most of the cases. One could perhaps have accepted such estimates if $\beta$ were to be equal to 1.0 in some of the crops but not in all. But when it happens for all the crops, our estimates became questionable in spite of high R-bar square. This result does not seem to be a quirk of the estimating procedure such as a monotonicity of the likelihood function with respect to $\beta$ because estimates obtained in such a way by Cummings do not show the same rigid pattern of $\beta$ always taking a corner value of the possible range[6].

Acceptance of these estimates would have automatically meant that farmers in India have only naive expectations. However, we believe this cannot be the case with all farmers of all crops.

The above difficulty could not be overcome even by alternative specifications involving prices, trend variable and logarithmic values of the variables and so on. Let us refer back to the Nerlovian price expectation formulation:

$$P^*_t = \beta P_{t-1} + (1-\beta)P^*_{t-1}$$

which is a first order difference equation.

The solution of this equation is

$$P_t^* = H(1-\beta)^t + \sum_{\lambda=0}^{t} \beta(1-\beta)^{t-\lambda} \cdot P_{\lambda-1}$$

where H is a constant. Under certain assumptions made on initial conditions etc., this can be rewritten as:

$$P_t^* = \sum_{\lambda=0}^{t} \beta(1-\beta)^{t-\lambda} \cdot P_{\lambda-1} \quad .$$

That is, the expected "normal" price is a weighted average of past prices. Now, suppose, the relation between actual and expected prices at period t is: $P_t = P_t^* + W_t$ where $W_t$ comprises of all the random shocks and disturbances etc. Now,

$$P_t^* = \sum_{\lambda=0}^{t} \beta(1-\beta)^{t-\lambda}(P_{\lambda-1}^* + W_{\lambda-1})$$

implies that the weights attached to the (expected) price-value and also the random-disturbances are the same in each period. This obviously cannot be the case for a meaningful expectation notion.

Clearly, the revenue expectation equation needed to be formulated differently. Presence of a secular trend in the revenues could lead to a result where $\beta$ would seem to exceed 1. If expectations reflect secular trend in relative revenues, it would seem reasonable to assume that farmers observe the levels of prices and revenues overtime, and especially also are aware of any random shocks, which may be of short-run nature, that the variables were subjected to. The future expected price or revenue should adequately account for this process of movement and occasional random shocks.

A more satisfactory model seemed to be an ARIMA type model[7]. Box and Jenkins have developed a satisfactory econometric methodology to estimate a model to forecast the value of a variable by being able to identify the stationary and random components of each past value of it.

Their methodology involves a) identification of an "appropriate" model to suit the time series based on the auto-correlation and partial auto-correlation functions, b) fitting the identified model to the time series using the likelihood function to yield maximum likelihood estimates of the parameters, c) a diagnostic check, on the basis of certain stationary conditions and Chi-square tests, to verify whether the identified model is adequate for representing the time series. We postulate a Box-Jenkins model for the independent estimation of crop-revenue expectation functions first. These functions would later be plugged in the acreage allocation and adaptation scheme; and acreage-response functions are then estimated.

Estimation of Crop Revenue Expectation Functions

In this section we present the estimates of revenue expectation functions based on Box-Jenkins methodology[8]. A time series constituting a discrete linear stochastic process of $\{X_t\}$ can be written as:

$$(4.3.1) \quad X_t = \mu + \psi_o \varepsilon_t + \psi_1 \varepsilon_{t-1} + \psi_2 \varepsilon_{t-2} + \dots +$$

where $\psi_j$s are the weights attached to random-disturbances of different time periods. $\mu$ is a constant that determines the level of the time series process. If a given time series is stationary it fluctuates randomly about a constant mean. If it is not stationary it does not have a natural mean. If (4.3.1) is a convergent sequence then the process is said to be stationary and if it is a divergent one it is said to be non- stationary. Some non-stationary time series can be reduced to stationary series (which are then called "homogenously non-stationary", before reduction) by applying an appropriate degree of differencing 'd' on the original series.

$\nabla$, the differencing operator and B, the backward shift operator, are defined as follows:

$$\nabla^d X_t = (1-B)^d X_t$$

where

$$B^n X_t = X_{t-n} \quad .$$

Then a stationary series $\{Y_t\} = \{\nabla^d X_t\}$ can be obtained from a non-stationary series $\{X_t\}$. A "parsimonious" approach towards estimation requires rewriting the sequence (4.3.1) as an equation containing on r.h.s. only a finite number of lagged dependent variables 'p' and moving average variables 'q'. Then, a Box-Jenkins Auto-Regressive Integrated Moving Average Process (ARIMA) can be written for a time series $\{\Pi_t\}$ as:

$$(4.3.2) \quad \Pi_t = \phi_1 \Pi_{t-2} + \phi_2 \Pi_{t-2} + \phi_3 \Pi_{t-3} + \cdots + \mu + \theta_1 w_{t-1} + \theta_2 w_{t-2} + \theta_3 w_{t-3} + \cdots +$$

where $w_t$ is the white-noise or random disturbance in period t. (4.3.2) is the ultimate equation to be estimated in which the number of parameters depends on the values of p,q and the degree of differencing d. Henceforth in this paper, those ARIMA schemes that we estimate are indicated as p,q,d, in that order. For each crop we applied the following ARIMA schemes to estimate[9] $\Pi_{igt} = (P_{igt} \cdot Y_{igt})$ as a function of past revenues and white-noise (random disturbance) values in the form of (4.3.2):

(p,q,d): (1,1,0), (1,2,0), (2,1,0), (1,1,1), (1,2,1), (2,1,1).

Of these six schemes, the best one was selected on the basis of a diagnostic checking consisting of:

1. stationary conditions of the series,
2. Chi-square test on the residual auto-correlations.

The selected schemes, the results of the estimates and the Chi-square values based on the residual auto-correlation are presented in Table 4.2.

Each of these estimated equations show a stationary process for the sequential values overtime of a variable under consideration. These estimations provide the appropriate weights to be given for the past values of the stationary and random components of a variable. The farmers' expected normal revenue will be (subscripts for the crop dropped):

$$(4.3.3) \quad \Pi_t^* = \Pi_t - w_t = \phi_1 \Pi_{t-1} + \phi_2 \Pi_{t-2} + \phi_3 \Pi_{t-3} + \dots + \mu$$

$$+ \theta_1 w_{t-1} + \theta_2 w_{t-2} + \theta_3 w_{t-3} + \dots + \quad .$$

The values $\hat{\Pi}_t^*$ from (4.3.3) will now be used in re-estimating the Nerlovian model presented in the next section.

## 4.4 Estimation of the Acreage Response Model

While re-estimating the model, some additional modifications were also made to the equations presented in section 4.2.

1. Instead of treating the revenues of the main and competing crops as separate variables, we introduced only one variable $Z_{igt}$ defined as follows:

$$(4.4.1) \quad Z_{igt} = \hat{\Pi}_{igt} / (\hat{\Pi}_{K1 \cdot g \cdot t} \cdot \hat{\Pi}_{K2 \cdot g \cdot t})^{1/2}$$

or

$$= \hat{\Pi}_{igt} / \tfrac{1}{2} (\hat{\Pi}_{k1gt} + \hat{\Pi}_{k2gt})$$

where

$$\Pi_{igt} = P_{igt} \cdot Y_{igt}$$

Table 4.2. Box-Jenkins ARIMA-Process schemes and results of expectation function estimations.

$$\pi_t = \phi_1\pi_{t-1} + \phi_2\pi_{t-2} + \phi_3\pi_{t-3} + \mu + \theta_1\omega_{t-1} + \theta_2\omega_{t-2} + \omega_t$$

$X^2$ = Chi-square on the residual auto-correlations

$\omega_t$ = White noise in time t

| | Variable $(\pi_t)$ | (ARIMA) Scheme | $\phi_1$ | $\phi_2$ | $\phi_3$ | $\mu$ | $\theta_1$ | $\theta_2$ | $\omega_{1972}$ | $\omega_{1973}$ | $\omega_{1974}$ | $X^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bajra Price | 110 | 0.9364 | | | 8.0810 | -0.7367 | | 31.65 | 49.58 | 13.00 | 6.99 |
| 2 | Bajra Yield | 120 | 0.8473 | | | 0.0547 | 0.1092 | 0.5128 | 0.452 | 0.332 | 0.540 | 8.21 |
| 3 | Barley Revenue | 121 | 1.2735 | -0.2735 | | | 0.9288 | -1.4495 | 16.604 | 74.763 | 0.00 | 4.31 |
| 4 | Sugarcane Revenue | 111 | 0.4641 | 0.5359 | | | -0.8154 | | 284.605 | -14.462 | 0.00 | 7.45 |
| 5 | Cotton Revenue | 121 | 0.5718 | 0.4282 | | | 0.4374 | -0.7503 | - 4.444 | 18.277 | 0.00 | 6.29 |
| 6 | Groundnut Revenue | 211 | 0.0613 | -0.0497 | 0.9884 | | -0.2528 | | -14.014 | 153.892 | 0.00 | 3.77 |
| 7 | Gram Revenue | 121 | 0.7787 | 0.2213 | | | 0.2960 | -0.6019 | 71.154 | - 5.263 | 0.00 | 6.39 |
| 8 | Jute Revenue | 121 | 0.6927 | 0.3074 | | | -0.1676 | 0.3014 | 13.143 | -68.96 | 0.00 | 5.98 |
| 9 | Jowar Revenue | 121 | 1.6994 | -0.6994 | | | 0.3521 | -0.7676 | 36.258 | 44.130 | 0.00 | 5.76 |

ARIMA Process: Autoregressive Integrated Moving-average Process

Scheme : Nature of ARIMA Process. The numbers representing the process are written in the order of P, Q, D where P = number of autoregressives.

Table 4.2. Box-Jenkins ARIMA-Process schemes and results of expectation function estimates.

$$\pi_t = \phi_1\pi_{t-1} + \phi_2\pi_{t-2} + \phi_3\pi_{t-3} + \mu + \theta_1\omega_{t-1} + \theta_2\omega_{t-2} + \omega_t$$

$X^2$ = Chi-square on the residual auto-correlations

$\omega_t$ = White noise in time t

| | Variable ($\pi_t$) | (ARIMA) Scheme | $\phi_1$ | $\phi_2$ | $\phi_3$ | $\mu$ | $\theta_1$ | $\theta_2$ | $\omega_{1972}$ | $\omega_{1973}$ | $\omega_{1974}$ | $X^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Mesta Revenue | 120 | 0.8447 | | | 65.7772 | 0.2742 | 0.0349 | 89.186 | 1o.514 | 105.782 | 9.30 |
| 11 | Maize Revenue | 111 | 0.6019 | 0.3981 | | | -0.2145 | | 61.995 | 123.436 | 0.00 | 5.77 |
| 12 | Maize Price | 121 | 1.7914 | -0.7914 | | | 0.3660 | -0.6225 | 49.023 | 65.896 | 0.00 | 5.71 |
| 13 | Maize Yield | 120 | 0.9719 | | | 0.0264 | 0.9729 | -1.2282 | - 0.018 | - 0.048 | - 0.041 | 8.97 |
| 14 | Rice Revenue | 111 | 0.8705 | 0.1296 | | | -0.9236 | | 65.422 | 9.374 | 0.00 | 7.87 |
| 15 | Ragi Revenue | 111 | 0.4856 | 0.5144 | | | -1.4122 | | 55.297 | 36.927 | 0.00 | 5.02 |
| 16 | Rape & Mustard Revenue | 211 | 0.0069 | 0.2066 | 0.7866 | | -0.4297 | | 27.818 | 39.435 | 0.00 | 9.12 |
| 17 | Sesamum Revenue | 211 | 0.5887 | -0.4238 | 0.8351 | | -0.4254 | | 6.685 | 17.001 | 0.00 | 6.67 |
| 18 | Tobacco Revenue | 121 | 0.2405 | 0.7595 | | | -1.2292 | -0.9618 | 8.465 | 32.876 | 0.00 | 5.72 |
| 19 | Wheat Revenue | 211 | 0.2497 | 0.4024 | 0.3480 | | -0.7508 | | 8.749 | 234.803 | 0.00 | 3.06 |

Q = No. of moving averages and D = Degree of differential applied to make the original "homogeneously nonstationary" series stationary.

$\mu$ = A constant which is equal to the mean of the series if D = O.

$Z_{igt}$ gives the revenue of crop i relative to the competing crops k1 and k2 computed on the basis of either geometric or arithmetic average; and (^) denotes the estimated value obtained from the Box-Jenkins exercise.

2. We also introduced different combinations of the variables, defined already in a previous section, $(Igt/I_{Gt})$, $(Ist/I_{Gt})$ and $(I_{Gt})$, into the system.
3. The model was specified in a multiplicative way as follows:

$$A^*_{igt} = a_o \cdot (Z^*_{igt})^{a_1} (R_{igt})^{a_2} (Igt/I_{Gt})^{a_3} (Ist/I_{Gt})^{a_4} \cdot (I_{Gt})^{a_5} \cdot V_t \quad . \tag{4.4.2}$$

$$Z^*_{igt} = Z_{igt} \quad \text{as defined in (4.4.1)} \tag{4.4.3}$$

$$A_{igt} = (A^*_{igt})^{\gamma} (A_{igt-1})^{1-\gamma} \quad . \tag{4.4.4}$$

Substitution after taking logarithms yields the following reduced form equation:

$$\text{Log } A_{igt} = a_o^1\gamma + (1-\gamma) \log A_{igt-1} + a_1\gamma \log Z_{igt} + a_2\gamma \log R_{igt} + a_3\gamma \log \left(\frac{Igt}{I_{Gt}}\right) + a_4\gamma \log (Ist/I_{Gt}) + a_5\gamma \log (I_{Gt}) + \gamma \log V_t \quad , \tag{4.4.5}$$

where

$U_t = \log V_t$ is normally distributed as $N(o,\sigma^2)$.

While estimating equation (4.4.5) some essential points must be borne in mind[10]:

1. As the data used are of time-series there can be a possibility of auto-correlation.

In such a case application of the OLS would give unbiased estimates, but the sampling variances may be underestimated.

2. The presence of the lagged dependent variable on the right hand side (in the absence of the auto-correlation) leads to only consistent estimates which can be biased in small samples. However, the combination of both 1. and 2. yields not even consistent estimates if OLS is applied.
3. If the disturbance term and the dependent variable in equation (4.4.5) are correlated, it means that the disturbance term is correlated also with (at least) one of the explanatory variables especially under auto-correlation, which again gives biased estimates in small samples.
4. Moreover, under such circumstances the conventional Durbin-Watson test cannot be relied on, to test for auto-correlation. Though the presence of three or four exogenous variables (like rainfall, relative revenue, irrigation and so on) other than the lagged dependent variable on the right hand side helps reducing the asymptotic biases of the estimates in such cases[11], we decided to allow for auto-correlation outright. A first-order auto-correlation scheme was assumed and in the beginning we used Cochrane Orcutt technique in estimation. However, we suspected that this technique might be yielding only the local optimum at least in some cases[12]. Hence a scanning technique is preferred to Cochrane Orcutt technique for estimating the auto-correlation parameter $\rho$ in $U_t = \rho U_{t-1} + \varepsilon_t$. Equation (4.4.5) was estimated for 40 values of $\rho$ for each crop, over a range of $-1.00 \leq \rho \leq 1.0$ with a step size of 0.05 and observed the highest R-bar square.

Interestingly, however, for many of the crops the estimate of $\rho$ turned out to be zero, implying $U_t$ and $U_{t-1}$ are not correlated in which case the problem mentioned in 3. above also may not be there. One explanation for this might be due to the presence of estimated revenue term rather than the actual revenue term as one of the explanatory variables on the right hand side.

Data: Most of our data were taken from several volumes of the "Estimates of Area, Production of Principal Crops in India" of Directorate of Economics and Statistics Ministry of Food and Agriculture, Government of India. These essentially cover data on area, production, yield and irrigation area. Price data were collected from the Office of the Economic Adviser, Ministry of Industrial Development. Rainfall data corresponding to each crop separately were obtained from Ray (1977).

Equation (4.4.5) was estimated[13] for some selected crops in the groups. We obtained acceptable results for rice, wheat, groundnut, sugarcane, and tobacco at the very first instance.

For the crops ragi, jute, mesta, gram, barley and sesamum the results became acceptable only when their relative areas, relative to some other crops in the group, were estimated instead of areas. That is ragi/rice, jute/ragi, mesta/ragi, gram/wheat, barley/wheat, sesamum/groundnut and rape and mustard/sesamum were estimated instead of the areas under ragi, jute, mesta, gram, barley, sesamum, rape and mustard. In these cases $A_{igt}$ in equation (4.4.5) represents such relative areas (i.e., $A_{igt}$ is replaced by $A_{igt}/A_{jgt}$ meaning area of i-th crop relative to that of j-th crop in group g.

The results of estimation were presented in table 4.3. As can be observed, for all the above crops (i.e., jowar, bajra, maize and cotton excepted) the coefficients of the revenue terms are positive. These are significant at 5% level for jute, mesta, wheat, barley, rape and mustard, sugarcane and tobacco. This significance varies between 10 to 20% level for rice, ragi, cotton and sesamum crops. However, these coefficients for gram and groundnut were not significant even at 20% level. The result that groundnut acreage response to revenue was insignificant is somewhat perplexing especially because it is a commercial crop.

Coming to the coefficients of ($A_{igt-1}$) term, i.e., $(1-\gamma)$ where $\gamma$ is the adjustment parameter, it can be explained as follows:

1. If $(1-\gamma)$ is significantly different from zero, then $\gamma$ is significantly different for one and
2. If $(1-\gamma)$ is not significantly different from zero, then $\gamma$ is not significantly different from one.

Then 1. implies farmers could not achieve their desired levels but could adjust their acreage in that direction to some extent. 2. implies they could adjust their acreage up to the desired levels. For rice, as could be seen, $(1-\gamma)$ is significantly'' different from zero and almost equal to one which means rice farmers could not adjust their acreage towards the desired levels.

This can be understood from the fact that rice already forms a major and the most important crop in India, accounting for 23% of the total, and also in view of the difficulties involved in bringing more and more area under cultivation and especially rice cultivation. Jute, wheat, cotton, groundnut, sesamum and rape and mustard are the other crops which also exhibit the same phenomenon but the adjustment parameter $(\gamma)$ is not so low as it is with rice. Ragi, mesta, gram, sugarcane, and tobacco are the crops for which this coefficient is not significant.

Coming to the coefficients of rainfalls and irrigated areas: except in the case of sugarcane, gram and barley , the coefficient of rainfall is always positive. As far as the irrigation is concerned, a positive coefficient of $(Igt/I_{Gt})$ indicates substitution of the particular crop for the areas of the competing crops in that group and a negitive coefficient indicates vice versa meaning that as irrigation facilities for that group increase, other crops are preferred. This argument can be extended with respect to the coefficient of $(I_{Gt})$ which indicates the effects of increasing the total irrigated area in the country on the area devoted to the particular crop. The reason for including $I_{Gt}$ as a variable is that many irrigation facilities in India are storage schemes which permit transfer of water across seasons and regions, i.e., across our groups. Moreover, irrigation schemes in India are designed for extensive rather than intensive irrigation. The fluctuations in irrigation availability due to rainfall fluctuation can be significant. The sign of the coefficient of $(Ist/I_{Gt})$ indicates the substitution trends between the crop under the question and sugarcane.

Table 4.3. Results of area estimation.

| S.No | Crop | Group | $A_{igt-1}$ | Rainfall | Revnrtag | Revnrate | IASO/IARGROSS | IACN/IARGROSS | IARGROSS | CONSTANT | DEGREES OF FREEDOM | $\bar{R}^2$ / DW | RHO | COMPETING CROPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Rice | 1 | 0.9854 (88.89) | 0.0798 (3.27) | 0.0305 (1.64) | | 0.0592 (1.76) | | | -0.000002 (-1.68) | 15 | 95.81 (1.82) | (-0.4) | Ragi Sugarcane |
| 2 | Rice | 1 | 0.9823 (77.87) | 0.0652 (2.67) | 0.0314 (1.57) | | 0.0685 (1.79) | -0.0236 (-0.75) | | -0.000003 (-1.73) | 14 | 95.14 (1.73) | (-0.4) | Ragi Sugarcane |
| 3 | Ragi/Rice | 1 | 0.1078 (0.42) | 0.1348 (0.79) | 0.1167 (1.32) | | 0.2421 (1.05) | | -0.2464 (-2.11) | -0.000003 (-0.19) | 14 | 49.00 (2.09) | (-0.15) | Rice Jute |
| 4 | Jute/Ragi | 1 | 0.3634 (2.08) | 0.1717 (1.44) | | 0.5694 (3.32) | 1.5201 (1.60) | -0.3301 (-1.20) | 0.9331 (2.18) | -11.8880 (-2.86) | 13 | 57.21 (2.27) | (0.00) | Rice Ragi |
| 5 | Jute/Ragi | 1 | 0.3636 (2.04) | 0.1880 (1.55) | 0.5573 (3.20) | | 1.5485 (1.60) | -0.3287 (-1.17) | 0.9489 (2.18) | -11.68 (-2.75) | 13 | 55.78 (2.34) | (0.00) | Rice Ragi |
| 6 | Mesta/Ragi | 1 | 0.3091 (1.42) | 0.0397 (0.27) | | 0.0874 (2.44) | 2.180 (1.76) | | 1.6926 (2.72) | -17.7745 (-3.06) | 14 | 59.16 (2.33) | (0.00) | Rice Ragi |
| 7 | Wheat | 2 | 0.2599 (2.20) | 0.0964 (5.77) | 0.0678 (2.71) | | | | 0.8081 (6.70) | -1.8796 (-2.89) | 15 | 96.36 (2.22) | (0.00) | Gram Barley |
| 8 | Wheat | 2 | 0.2568 (2.19) | 0.0995 (5.90) | | 0.078 (2.77) | | | 0.8132 (6.78) | -1.7531 (-3.08) | 15 | 96.43 (2.33) | (0.00) | Gram Barley |
| 9 | Gram/Wheat | 2 | 0.1627 (0.69) | -0.0911 (-0.82) | | 0.0678 (0.71) | | | -1.4081 (-3.50) | 14.5845 (3.53) | 15 | 92.97 (2.00) | (0.00) | Wheat Barley |

*All variables are in their logarithmic form

'Revnrtag': relative revenue of the crop against its competing crops where the competing crops revenue is computed as a linear average.
'Revnrate': same as 'revenrtag' except that the competing crops revenue is computed as a geometric average (see equation (4.4.1).

Table 4.3. Results of area estimation.

| S.No | Crop | Group | $A_{igt-1}$ | Rainfall | Revnrtag | Revnrate | IASO / IARGROSS | IATOSD / IARGROSS | IARGROSS | CONSTANT | DEGREES OF FREEDOM | $\bar{R}^2$ / DW | RHO | COMPETING CROPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Barley/Wheat | 2 | 0.4320 (3.09) | -0.0399 (-0.99) | 0.0898 (2.34) | | | | -0.91110 (-3.52) | 8.7462 (3.42) | 15 | 95.35 (2.37) | (0.00) | Wheat Gram |
| 11 | Barley/Wheat | 2 | 0.4388 (3.14) | -0.0388 (-0.96 | | 0.0924 (2.34) | | | -0.8985 (-3.46) | 8.56 (3.32) | 15 | 95.35 (2.38) | (0.00) | Wheat Gram |
| 12 | Cotton/Maize | 3 | 0.9008 (9.46) | 0.0182 (1.36) | 0.0654 (1.82) | | | | | -0.000051 (-1.84) | 16 | 86.90 (1.63) | (0.10) | Jowar Miaze |
| 13 | Groundnut | 4 | 0.9480 (27.79) | 0.0895 (1.24) | | 0.0465 (0.91) | | | | 0.000019 (2.53) | 16 | 78.98 (1.88) | (-0.35) | Sesamum |
| 14 | Sesamum/ Groundnut | 4 | 0.5489 (6.37) | 0.0858 (0.90) | | 0.0737 (1.54) | | | | -0.7785 (1.76) | 16 | 69.16 (2.15) | (0.00) | Groundnut Groundnut |
| 15 | Rape & Mus-tard/Sesamum | 4 | 0.3617 (2.68) | 0.0787 (2.21) | | 0.1336 (2.17) | -0.917# (-1.30) | 0.1974 (2.94) | | 0.000011 (-2.11) | 14 | 75.29 (1.70) | (-0.6) | Sesamum Sesamum |
| 16 | Sugarcane | 8 | 0.0949 (0.42) | -0.2296 (-1.47) | 0.1989 (1.98) | | | | 0.7230 (3.83) | 0.000014 (0.80) | 15 | 68.58 (1.70) | (0.25) | Ribe Wheat |
| 17 | Sugarcane | 8 | 0.0852 (0.38) | -0.2473 (-1.58) | | 0.2020 (2.10) | | | 0.7233 (3.90) | 0.00014 (0.84) | 15 | 69.27 (1.67) | (0.25) | Rice Wheat |
| 18 | Tobacco | 9 | 0.1762 (1.45) | 0.1559 (3.39) | | 0.1140 (4.58) | | | | 3.7282 (5.55) | | 75.60 (1.85) | | No competing crops |

*'IASO' : irrigation area of the soil to which that group belongs ($I_{gt}$).

'IARGROSS': gross irrigated area of all the crops taken together in the country ($I_{Gt}$).

'IACN' : irrigated area of sugarcane ($I_{st}$).

*IATOSD: irrigated area of total oilseeds.

# : proportion of the irrigated area of the competing non-oilseed crops.

Table 4.3. Results of area estimation.

| S.No | Crop | Group | $A_{igt-1}$ | Rainfall | Exp. Price | Exp. Yield | $\frac{IASC}{IARGROSS}$ | IARGROSS | CONSTANT | DEGREES OF FREEDOM | $\frac{\bar{R}^2}{DW}$ | RHO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | Maize | 3 | 0.0605 (0.25) | 0.0153 (0.25) | | | | 0.7631 (3.94) | 0.000004 (1.20) | 16 | 92.49 (1.70) | (0.65) |
| 20 | Maize | 3 | 0.552 (3.59) | 0.1107 (1.61) | 0.1454 (4.87) | 0.1083 (0.78) | | | 2.5942 (2.38) | 15 | 95.73 (2.71) | (0.00) |
| 21 | Maize | 3 | 0.4993 (2.50) | 0.0882 (1.41) | 0.1230 (4.27) | | | 0.2104 (1.10) | 1.1541 (1.36) | 15 | 95.90 (2.26) | (0.00) |
| 22 | Maize | 3 | 0.13 (0.51) | 0.0192 (0.33) | | -0.2021 (-1.40) | | 0.7060 (3.40) | 0.000004 (1.38) | 15 | 92.67 (1.77) | (0.80) |
| 23 | Bajra | 3 | 0.1371 (0.60) | 0.1803 (2.54) | | | 0.7751 (3.72) | | 8.9726 (3.86) | 16 | 55.08 (1.98) | (0.00) |
| 24 | Bajra | 3 | 0.1697 (0.73) | 0.0729 (1.19) | | | | 0.2818 (3.43) | 4.5248 (2.44) | 16 | 51.76 (1.68) | (0.00) |
| 25 | Bajra | 3 | 0.1637 (0.73) | 0.1545 (2.12) | 0.0574 (1.23) | 0.4742 | 0.4742 (1.49) | | 7.9027 (3.23) | 15 | 56.60 (2.06) | (0.00) |
| 26 | Bajra | 3 | 0.2678 (1.17) | 0.1213 (1.60) | | 0.0789 (1.65) | 0.5626 (2.39) | | 7.6335 (3.26) | 15 | 59.74 (2.32) | (0.00) |
| 27 | Bajra | 3 | 0.4043 (1.92) | 0.0560 (0.87) | 0.0773 (2.07) | 0.0770 (1.49) | | | 5.0405 (2.72) | 15 | 56.50 (2.29) | (0.00) |
| 28 | Jowar/ Maize | 3 | 0.3065 (1.42) | 0.0341 (0.69) | | | | -0.7492 (-3.38) | 6.4956 (3.29) | 16 | 97.51 (0.00) | (0.00) |

*Figures in brackets are the corresponding 't' values.

See table 3 for the composition of crops in the groups.

*RHO: auto-correlation parameter in $Ut = \rho U_{t-1} + \varepsilon_t$

DW : Durbin-Watson statistic.

In the above discussion, the crops maize, jowar and bajra were not included. A separate analysis was required for these crops with a different hypothesis.

When the model was applied as presented above, to these crops, our estimation results showed consistently negative and significant coefficients for the revenue variable. The R-bar Square values were also satisfactory for all the crops and in fact, quite high for maize.

In fact, this result, we thought, is plausible. It may be noted that all these three crops are primarily subsistence crops. If these crops are grown primarily for self-consumption, then farmers need only a fixed quantity of output in a given period and they adjust the allocation of area only to grow that much of output. Now, if the land productivity is increased through technological factors etc., then they need to allocate less area for growing the same amount of output and hence an increase in the yield of these crops should have a negative effect on the acreage response. However, an increase in the price of these grains output will lead to a positive acreage response because then, the farmers would like to grow more for sale. Under these circumstances, the net effect on the revenue per acre, which is price multiplied by yield, can be a negative acreage response.

This hypothesis was tested by dropping the revenue variable from the model and substituting yield and price variables separately and also together. For this purpose, Box-Jenkins analysis was carried out for the yield and price variables, separately, of these crops to estimate expected values. Tables 4.2 and 4.3 show these results also.

As can be seen, the results of maize support the plausibility of the hypothesis and the R-bar Square values range over 92% to 96%. The analysis of bajra does not seem to support this hypothesis so clearly; however, the estimations based on price and yield variables were far better than those based on revenue variable. Hence only these were included and presented here.

Similar was the case with jowar. However, in the case of jowar 1. relative area with respect to maize only gave a good result and 2. inclusion of neither revenue nor price nor yield gave better results than the one shown in Table 4.3.

As was mentioned earlier, an acreage response analysis was not done for the groups 5,6,7 and 8 which contain fruits, vegetables, condiments and spices, rubber, coffee and tea. Their acreages were estimated merely as a percentage of the country's total gross cropped area. This can be later seen as a part of the allocation scheme presented in the next section.

## 5 ALLOCATION SCHEME

There are very few studies in agricultural economics dealing with area allocation models where the estimated areas of all crops put together would add up to the country's total gross cropped area. Teekens and Jansen (1977) discuss the problem of estimation of the parameters of a multiplicative allocation model. The problem is to estimate the share of each crop in the country's total cropped area:

$$Y_i = \prod_{k=1}^{K} Z_{ik}^{\alpha_K} \; v_i \Big/ \sum_{j=1}^{N} \prod_{k=1}^{K} Z_{jk}^{\alpha_K} \; v_j \;,$$

$$i = 1,\ldots,N$$

where

$v_i$ , a random term, is such that

$E[v_i] = \lambda$ (a constant),

$\mathrm{Cov}[v_i, v_j] = [\phi_{i,j}]$

and the vector

$v' = [v_i]$ , has a multivariate log normal distribution.

The usual procedure adopted in the cases of such specification is to estimate the logarithmic form of the above equation. It could be shown that:

$$U = [U_i] = [\log \nu_i] \sim N(\mu, \Sigma)$$

with mean

$$\mu = [\mu_i] = [\log \lambda - \frac{1}{2} \log (\phi_{ii} + 1)]$$

and covariance matrix

$$\Sigma = [\sigma_{ij}] = [\log (\phi_{ij} + 1) \quad .$$

That is, the mean is a function of the covariance matrix elements. For the complications involved in estimating the parameters of this model, the authors suggest a special procedure based on the (singular) distributional property of the vector $Y = [Y_i]$ that $\Sigma$ Yi = 1.

However, adoption of this procedure requires an a-priori knowledge of $[\phi]$ and that involves at least some arbitrariness to start with.

In this section we will present a different allocation scheme, where for the major and important crops of India, the areas as such, but not the shares, are estimated. In the next few lines this scheme is elaborated. Let us first look at what we have estimated in section 4. This information is provided group-wise in the following tables (5.1) and (5.2). Table (5.1) is just the same as table (4.1) reproduced here for ready reference of the crops involved in the system. Table (5.2) shows the dependent variables in the estimated acreage-response equations corresponding to each crop in table (5.1).

Table 5.1. List of the crops and groups in the system.
All groups ($A_G$ = Total gross cropped area in the country).

| Group (g): | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Crop (i) : | | | | | | | | | | |
| 1 | Rice | Wheat | Maize | Groundnut | Fruits & Vegetables | Rubber | Coffee | Tea | Sugar cane | Tobacco |
| 2 | Ragi | Gram | Bajra | Sesamum | Condiments & Spices altogether | | | | | |
| 3 | Jute | Barley | Jowar | Rape & Mustard | | | | | | |
| 4 | Mesta | | Cotton | | | | | | | |
| $Q_g$ | Residual | Residual | Residual | Residual | | | | | | |
| Group Total ($A_g$) = $\sum_i A_{ig} + Q_g$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ | $A_9$ | $A_{10}$ |

Table 5.2. Dependent variables in the acreage response equations. All groups ($A_G = \bar{A}_G$ given)

| Group (g) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Crop (i) | | | | | | | | | | |
| 1 | Rice | Wheat | Maize | Groundnut | Fruits* etc. | Rubber* | Coffee* | Tea* | Sugar cane | Tobacco |
| 2 | Ragi / Rice | Gram / Wheat | Bajra | Sesamum / Groundnut | | | | | | |
| 3 | Jute / Ragi | Barley / Wheat | Jowar / Maize | Rape & Mustard / Sesamum | | | | | | |
| 4 | Mesta / Ragi | | Cotton / Maize | | | | | | | |

*Not estimated as Nerlovian model, but as a percentage of $A_G$; see equations below (5.3).

In our scheme the country's total gross cropped area during time period 't' is known in advance based on the information exogenous to this scheme. Some of these factors were already mentioned earlier. Suppose this known value is $\bar{A}_{Gt}$:

$$(5.1) \quad A_{Gt} = \bar{A}_{Gt} \quad .$$

Next task would be to allocate this total area to several groups, first satisfying the definitional constraint:

$$(5.2) \quad A_{Gt} = \sum_g A_{gt}$$

where

$A_{gt}$

is the sum of the areas of all the crops in g-th group. The simplest way to allocate $A_{Gt}$ would be to express each $A_{gt}$ as a fixed proportion of the total. However, as we already know, $A_{gt}$ for groups 9 and 10, that is sugarcane and tobacco areas respectively, we need to allocate only $A_{Gt}$ net of the areas of these two groups (crops), to different other groups:

$$(5.3) \quad A_{gt} = \beta_g (A_{Gt} - A_{1\cdot 9\cdot t} - A_{1\cdot 10\cdot t}) \quad \text{for } g = 1,8$$

where

$\beta_g$

is the proportion of the g-th group area in the country's total. It may be noted that there is no constant term in the equations (5.3) and separate estimates of $\beta_g$ all add up to 1.

So far, we have merely shifted the allocation problem from $A_{Gt}$ to $A_{gt}$. Knowing $A_{gt}$, the real problem is to allocate the area for each group in that group g. It is here, that the estimated acreage response equations were made use of.

By definition, the sum total of the areas of all crops in a group (g) should be the total group area, i.e.,

$$(5.4) \quad A_{gt} = \sum_i (A_{igt}) + Q_{gt}$$

where

$$A_{igt}$$

is the area of i-th crop in group g and

$$Q_{gt}$$

is the residual area, net of the important crops in group g. However, it may be noted that we did not estimate for every i (crop) in every g (group) a function for $A_{igt}$. For some crops (i), it is the relative area, i.e., $A_{igt}/A_{jgt}$ (relative area of i-th crop with respect to j-th crop in group g) which was estimated, as is shown in table (5.2). Hence such estimated relative areas should be converted back to get estimates of absolute areas for these crops.

Now, from the details provided in table (5.2) let us write the following relations:

$$(5.5) \quad A_{igt} = \alpha_{ig} \cdot (A_{igt-1})^{\beta_{ig}} \cdot (Z_{igt})^{\gamma_{ig}} \cdot (X_{igt})^{\delta_{ig}} \cdot (V_{igt})$$

as equivalent to equation (4.4.5), i.e., X-variable represents the rest of the variables in (4.4.5); for

1. $\forall g$, except $g = 5$ to $8$, if $i = 1$

and

2. $g = 3$ if $i = 2$ .

Note that $A_{1 \cdot 9t}$ and $A_{1 \cdot 10t}$ are the areas of sugarcane and tobacco: (and see equations (5.3)).

$$(5.6) \quad A_{igt} = (A_{ig}/A_{1g})_t \cdot (A_{1g})_t$$

where

$$(5.7) \quad (A_{ig}/A_{1g})_t = \alpha_{ig} \cdot (A_{ig}/A_{1g})_{t-1}^{\beta_{ig}} \cdot (Z_{ig})_t^{\gamma_{ig}} \, (X_{ig})_t^{\delta_{ig}} \cdot \left(\frac{V_{ig}}{V_{1g}}\right)_t ,$$

where (5.7) is equal to equation (4.4.5), for:

1. $g = 1,2$ and $4$ if $i = 2$
2. $g = 2,3$ and $4$ if $i = 3$
3. $g = 3$ if $i = 4$.

$$(5.8) \quad (A_{igt}) = ((A_{ig})/A_{2g})_t \cdot (A_{2g})_t$$

where

$$(5.9) \quad (A_{ig}/A_{2g})_t = \alpha_{ig}(A_{ig}/A_{2g})_{t-1}^{\beta_{ig}} \, (Z_{ig})_{t-1}^{\gamma_{ig}} \, (X_{ig})_t^{\delta_{ig}} \, \left(\frac{V_{ig}}{V_{2g}}\right)_t$$

as equivalent to equation (4.4.5), for :

$g = 1$ if $i = 3$ and $4$.

Equations (5.5) to (5.8) calculate the sum total of the areas of all crops but not the residual areas ($Q_g$), for groups 1 to 4. These residual areas can be obtained from (5.4), because $A_{gt}$ for groups $g = 1$ to $8$ are known from (5.3). Note that $A_{gt}$ for $g = 9$ and $10$ are also known from equations (5.5) as the areas of sugarcane and tobacco.

In the above scheme, the basic and the most important equations to be estimated are equations (5.5), (5.7) and (5.9) which are precisely the estimated equations presented earlier in the section 'Estimation of the acreage response model', and table (4.3). The results of the estimation of (5.3) for $g = 1$ to $8$ where $\beta_g$ were estimated are presented in table (5.3).

Table 5.3. Results of group-area estimations.

| Group No | Crops in the Group | Gross Cropped Area-Area of (Sugarcane & Tobacco) | $\bar{R}^2$ | DW | RHO |
|---|---|---|---|---|---|
| 1 | Rice, Ragi, Jute, Mesta, Sannhemp, Small Millets, Tur, and other Pulses | 0.2788 (218.22) | 92.64 | 1.84 | 0.25 |
| 2 | Wheat, Gram, Barley, Small Millets, Tur and other Pulses | 0.2306 (48.22) | 57.18 | 1.90 | 0.60 |
| 3 | Jowar, Bajra, Maize and Cotton, Small Millets, Tur and other Pulses | 0.3565 (81.03) | 53.02 | 2.24 | 0.40 |
| 4 | Oilseeds: (Groundnut, Sesamum, Rape and Mustard, Castor, Linseed, Saflower, Nigerseed, Coconut and others) | 0.1105 (35.46) | 87.43 | 2.50 | 0.70 |
| 5 | Fruits, Vegetables, Condiments and Spices: (Potato, Black Pepper, Chilli, Ginger, Turmeric, Cardamom, Coriander, Arecanut, Guarseed, Banana, Sweet Potato, Tapioca, Papaya, Indigo and Opium) | 0.0329 (3.60) | 87.90 | 2.05 | 0.95 |
| 6 | Rubber | 0.0013 (13.58) | 97.83 | 1.25 | 0.90 |
| 7 | Coffee | 0.0009 (13.77) | 91.86 | 2.05 | 0.90 |
| 8 | Tea | 0.0023 (193.60) | 75.83 | 2.05 | 0.05 |

*Note: 1. The total area under small millets, tur and other pulses in the country was split into groups 1,2 and 3 above, based on sowing and harvesting periods of these crops. Hence, no double counting is involved.

2. Groups 9 & 10 comprise sugarcane and tobacco, respectively, for which acreage response equations were presented already in table 2.

In summary, the scheme of the acreage allocation is as follows:

1. Total gross cropped area in the country, projected independently, is exogenous to the system.
2. Most important crops like rice, wheat, maize, bajra, etc., are also projected independently.
3. Other relatively less important crops like ragi, gram, barley and jowar are projected in relation to the important crops mentioned in 2.
4. Still less important crops like fruits, vegetables, rubber, coffee and tea which account only a minor proportion of the total area are taken to be a fixed percentage.
5. After accounting for roughly around 80% of the total, the additivity is satisfied by means of the residual crops.

## 6. VALIDATION EXERCISE AND RESULTS

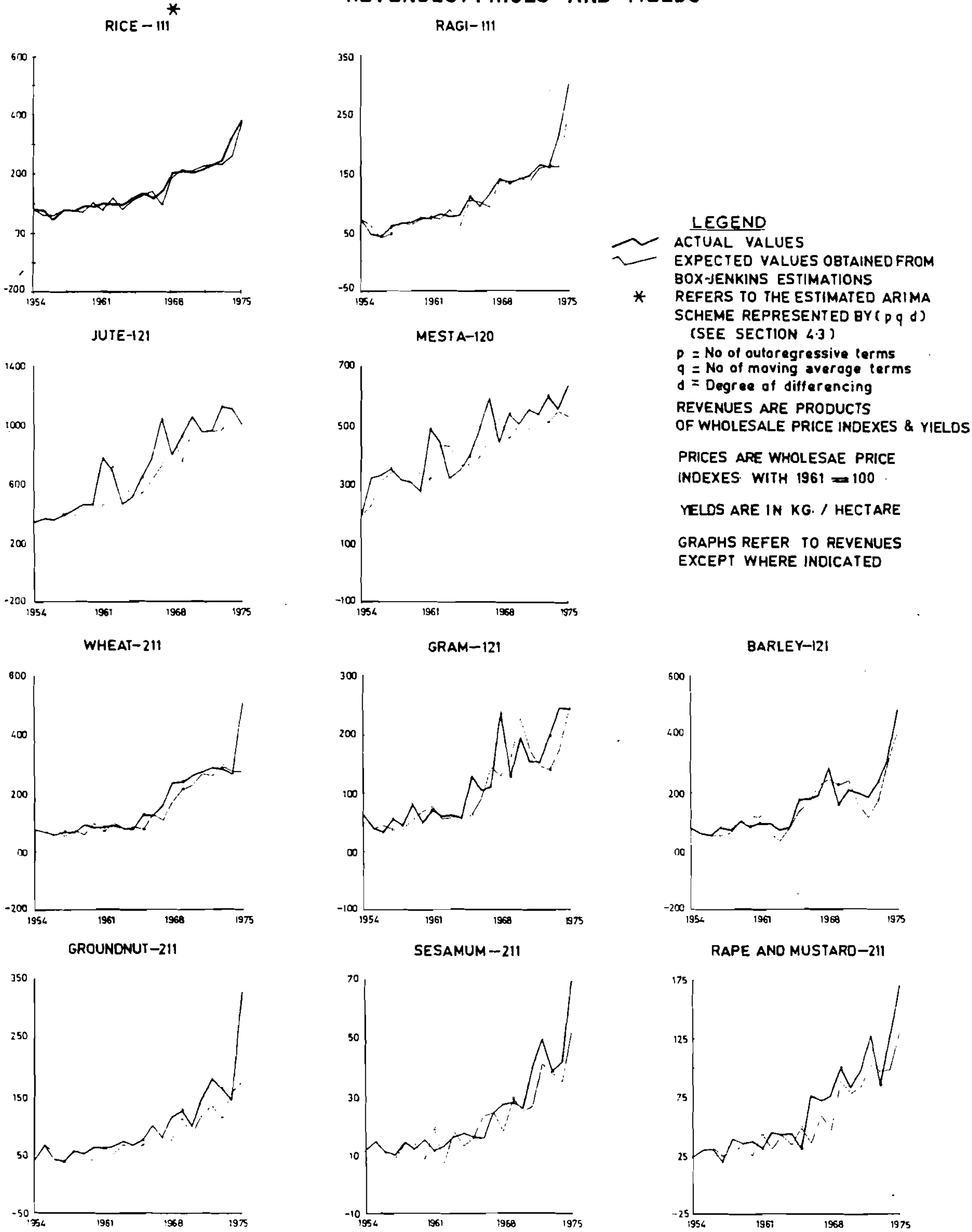
In the end, it was decided to carry out a simple validation exercise in order to check how best the estimated equations of the crop revenue expectation and acreage response can be relied upon for future projections. Details of these exercises are given in this section.

### 6.1 Validation Exercise for Crop Revenue Expectations

This part of the exercise merely consisted of comparing the estimated values of the expected revenue, price and yield of different crops obtained in section: 'Estimation of crop revenue expectation functions' with the actual values in the past of these variables. These values for each crop were plotted separatley and the plots are shown in graph 6.1.1. These plots correspond to the estimated equations presented in table 4.2.

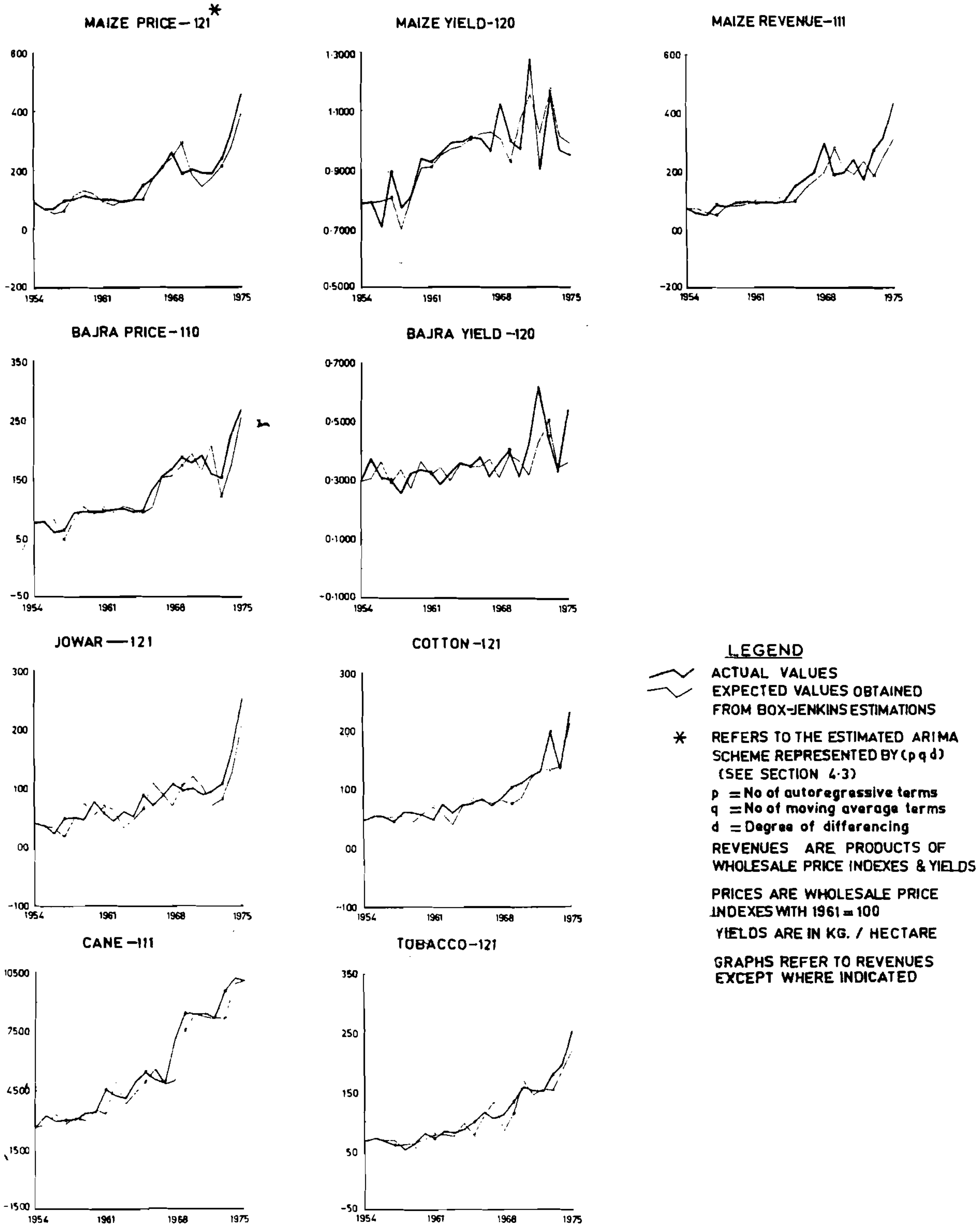
The extent of deviation of the estimated expected values based on the stationary and random components of the previous values from the actual values can be observed from the above plots. The expected values very closely follow up the actual values.

GRAPH 6.1.1
EXPECTED AND ACTUAL VALUES OF
REVENUES/PRICES AND YIELDS



GRAPH 6·1·1 (CONTINUED)

## EXPECTED AND ACTUAL VALUES OF REVENUES/ PRICES AND YIELDS



The performance, in this sense, of the estimated equations seems to be very good especially for the crops: Bajra, (Price and Yield), Maize (Revenue, Price and Yield), Rice, Ragi, Wheat and Tobacco. Except for Groundnut and Mesta, the results for other crops also are satisfactory. For Groundnut and Mesta, somehow the expected values deviated and turned out to be less than the actual values for many of the observations. This implies probably, that our search for an appropriate ARIMA scheme for these crops was not enough. This also explains the relatively unsatisfactory result obtained for acreage response for Groundnut, presented in section 'Estimation of the acreage response model'.

6.2 Validation Exercise for Acreage Response

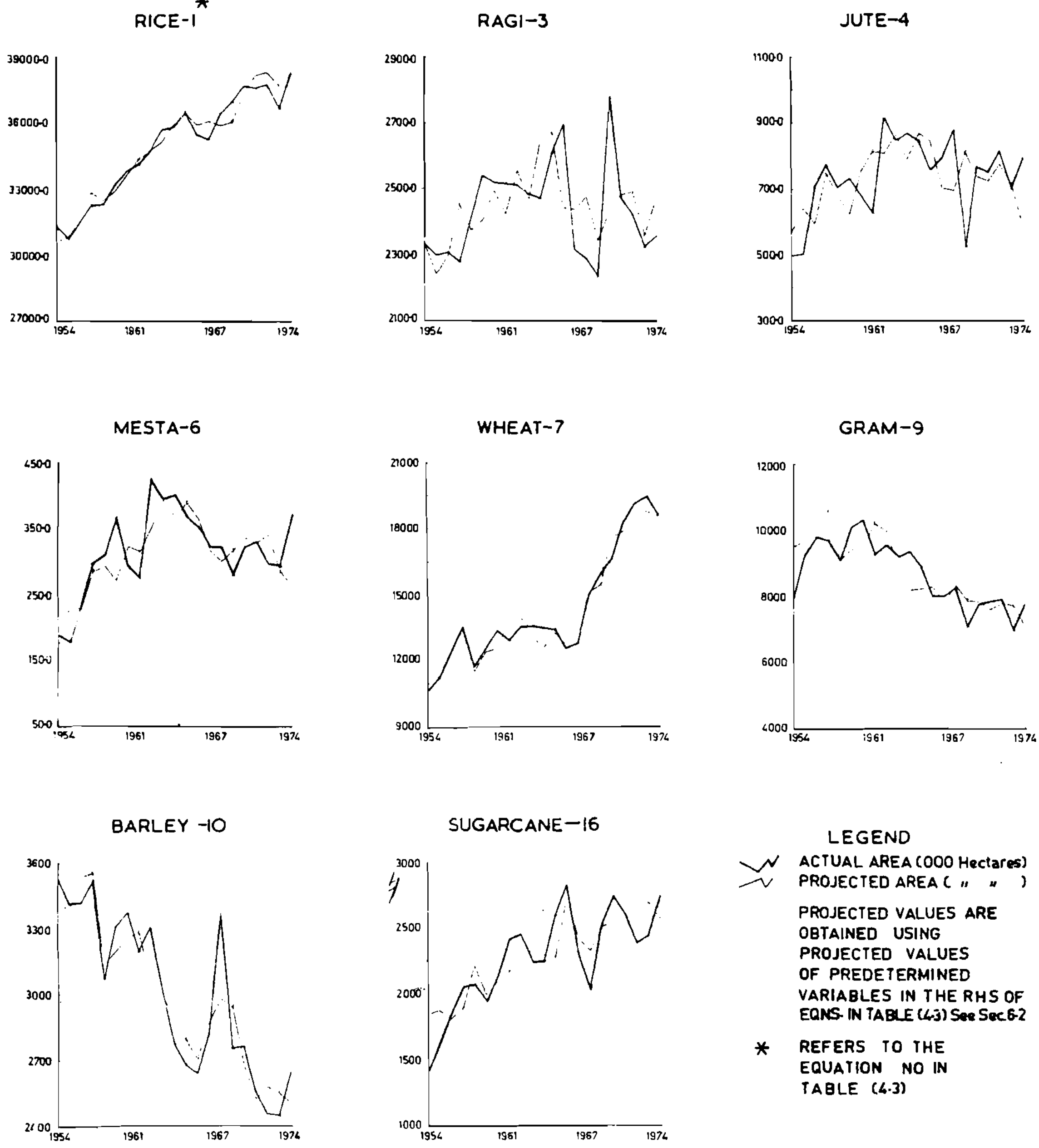
Since one of our major purposes was to use the allocation model for projection purposes in a year by year simulation model, a validation exercise was carried out to see how the model behaves when used for a past period. A validation exercise carried out over the period of estimation may seem to be just a look at the residuals of individual regressions. In our case, however, for most crops area projection would involve use in sequence of a number of equations which were estimated separately. Thus, this projection may give very different results than indicated by the residuals and a validation exercise is called for. Moreover, apart from the size of the errors, it is interesting to see to what extent the projections capture the turns--the ups and downs--in the data.

The estimation of (4.4.5) for each crop was carried out with actual data for all variables except for the revenue variable for which the numbers were obtained from the Box-Jenkins analysis. The right-hand side of equation (4.4.5) contains as one of the variables the proportion of irrigated area of group 'g' in the total irrigated area of the country, i.e., $(I_{gt}/I_{Gt})$ and also the proportion of irrigated area of sugarcane $(I_{St}/I_{Gt})$.

When this equation is made use of for the purpose of future projections naturally one cannot have the actual values of these right-hand side variables. Hence, first these right-hand side variables themselves must be projected and those projected values should be plugged in equation (4.4.5).

GRAPH G.1.2

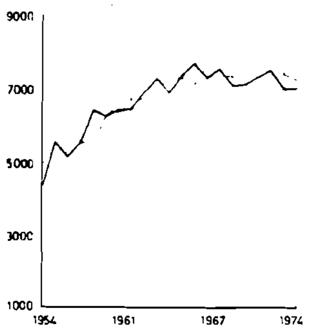
## ACTUAL AND PROJECTED AREAS



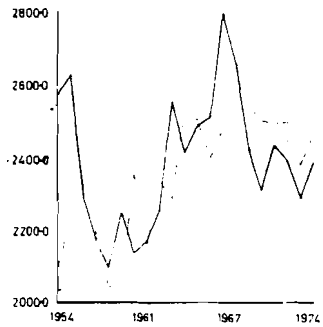
GRAPH 6.1.2 CONTINUED

## ACTUAL AND PROJECTED AREAS

GROUNDNUT-13*

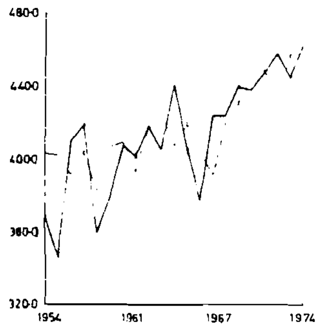



SESAMUM-14

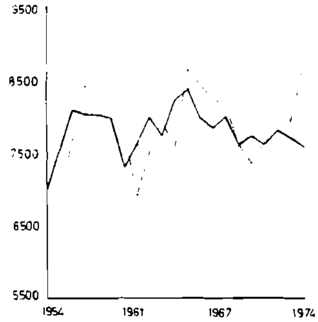



RAPE AND MUSTARD-15


TOBACCO-18




COTTON-12




LEGEND

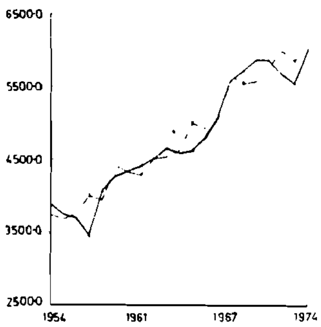
ACTUAL AREA (000 Hectares)

PROJECTED AREA ( " " )

PROJECTED VALUES ARE OBTAINED USING PROJECTED VALUES OF PREDETERMINED VARIABLES IN THE RHS Of EQNS. IN TABLE (4.3) See Sec(6.2)

* REFERS TO THE EQUATION NO IN TABLE (4.3)

MAIZE-20




BAJRA-26


JOWAR-28

As far as revenue is concerned, the estimated equations of crop revenue expectation functions obtained in section 'Estimation of crop revenue expectation functions' would serve the purpose. For rainfall, one can only expect that it would be normal, since rainfall in India has not been found to be predictable, or a given constant rainfall in the future, i.e., $R_{igt} = \bar{R}$ for the crops grown during the rainy season. For crops of the past monsoon season, rainfall may be considered as known. That leaves out the irrigation variables.

We decided to estimate separately the proportion of irrigated area of every group in the country's total irrigated area $(I_{gt}/I_{Gt})$.

The values obtained from these estimations would be used for carrying out the validation exercise. However, it must be noted while these estimations are carried out, the sum total of all these proportions added over different groups in the system should be one. Hence, we estimated the following sets of equations simultaneously along with a constraint equation towards the additivity:

$$(6.2.1) \quad \sum_{g=1}^{6} (I_{gt}/I_{Gt}) + v_{st} = 1$$

$$(6.2.2) \quad (I_{gt}/I_{Gt}) = a_1 + a_2(R_{gt}) + a_3\left(\frac{I_{gt-1}}{I_{Gt-1}}\right) + a_4(I_{Gt}) + V_{gt} \quad , \; g = 1,6$$

with g = 1 for Rice group, 2 for Wheat group, 3 for Jowar group, 4 for Oilseeds, 5 for Sugarcane, 6 for all other crops, and where $R_{gt}$ is the rainfall index for the group 'g' (we used the rainfall index of the main crop in that group, viz, rainfall index of rice for group 1 etc.) and other variables are as defined earlier in section 'Our experience with Nerlovian Model'.

Equation (6.2.2) expresses the proportion of irrigated area of group g in the total irrigated area as a function of predetermined variables, namely the last year's proportion, current year's rainfall and also the currently available total irrigated area.

Note that ($I_{Gt}$) is generally specified from outside the system. Hence use of the scheme behind (6.2.2) for projection is no problem.

Equations (6.2.1) and (6.2.2) were estimated simultaneously as a non-linear least squares problem[15]. The estimations correspond to the minimized sum of squares of the composite residual terms ($\Sigma V_{gt} + V_{st}$). A first-order auto-correlation scheme was also imposed on each individual disturbance term (v).

The estimated values obtained for the revenue (and price and yield as the case may be) and irrigation variables, obtained from the Box-Jenkins equations and (6.2.2) respectively would, when plugged in (4.4.5), yield the projected values of the acreage response. In the validation exercise, these projected values were compared with the actual values. Graph 6.1.2 shows the corresponding plots. These plots exactly correspond to the equations presented in table 4.3. As can be seen, the ultimate results are very promising. The expectation values following up the actual values fall within a close range. This performance of the estimated equations seems to be good especially for the crops: Rice, Wheat, Maize, Barley and Gram.

Even for the other crops, the estimated equations perform the prediction exercise satisfactorily.

However, one point worth noting, which emerges out of these plots, is that for some crops (for example, observe the plots of rice and sugarcane) whenever there are sudden dips or abnormal rises in the actual acreage in a year, the expected values for the corresponding, and also the next one or two years, fall widely apart from the actual values. This is due to the presence among the explanatory variables, of the acreage of only the previous year. If there is a sudden dip in the acreage in the previous year, that abnormal value of the acreage, not accounting for the general level and the possibility of recovery, is given undue weight in predicting the current year's value. Had we considered a weighted average of the acreage of a few past years in place of just the previous year's acreage ($A_{igt-1}$) by appropiately reformulating the acreage adjustment equation (4.4.4) (or equation 3.3) the ultimate result would have been much better.

Table 6.1. Results of group-wise estimation of irrigation area.

| S No. | Irrigation Area of the Group containing: | $a_1$ | $a_2 \cdot 10^2$ | $a_3$ | $a_4 \cdot 10^4$ | $\rho$ |
|---|---|---|---|---|---|---|
| 1 | Rice and other crops | -0.0176 | 0.0534 | 0.9666 | -0.0081 | -0.4486 |
| 2 | Wheat and other crops | 0.0119 | -0.0069 | 0.8949 | 0.0086 | 0.0604 |
| 3 | Jowar and other crops | 0.0541 | -0.0201 | 0.6372 | -0.0002 | -0.2832 |
| 4 | Oilseeds | -0.0092 | 0.0020 | 0.5848 | 0.0049 | -0.2507 |
| 5 | Sugarcane | 0.0355 | -0.0083 | 0.4820 | 0.0001 | 0.1953 |
| 6 | All other crops | 0.0791 | -0.0080 | 0.6066 | -0.0064 | -0.3498 |

1. $\sum_{g=1}^{6} (I_{gt}/I_{Gt}) + V_{st} = 1$ .

2. $\left[\frac{I_{gt}}{I_{Gt}}\right] = a_1 + a_2 R_{gt} + a_3 \left[\frac{I_{gt-1}}{I_{Gt-1}}\right] + a_4 I_{Gt} + V_{gt}$ , $g = 1,6$

3. $V_{it} = \rho V_{it-1} + \varepsilon_t$ , $i = g(1 \text{ to } 6)$ and s , $-1 \leq \rho \leq 1.0$ .

*Note: 1. The above estimates correspond to the minimized sum of: $\left[(\Sigma V_{gt} + v_{st})^2\right]$ .

2. The following are the estimated values of $\Sigma(I_{gt}/I_{Gt})$ for different time periods: 1.0016, 0.9975, 1.000, 1.0056, 0.9929, 1.0064, 1.0004, 0.9957, 0.9999, 1.0016, 0.9940, 1.0026, 1.0063, 1.0032, 1.0002, 0.9953, 0.9930, 1.0033, 0.9980, 1.0003, 1.0036, 0.9991, 0.9999.

## CONCLUSIONS

This paper aimed at modelling the land allocation decisions of the Indian farmers. We believe that rational farmers maximize their utility within the contexts of opportunities, uncertainties and risks. They cannot be expected to be insensitive to changing prices and profitabilities. We estimated acreage response for different crops using expected revenue instead of expected prices as a proxy for expected profits.

Simultaneously, we attempted to review the available approaches for the purposes of estimating acreage response and noted the influence of Nerlovian model based on adaptive-expectations and adjustment schemes. The basic scheme behind the Nerlovian model is quite general and is applicable for the study of acreage response behaviour even for developing economies like India. However, there seems to be a serious misspecification involved in this model as far as the formulation of the price expectation functions is concerned.

A better approach to formulate an appropriate revenue (or price, as the case may be) expectation function should be to identify clearly the "stationary" and random components involved in the past values of the variable and then attach appropriate weights to these components while predicting the future values. Nerlovian specification of the expectation function, unable to identify these components, attaches the same significance to them.

The use of Box-Jenkins methodology in estimating the crop revenue expectation functions and then using these estimates of expected revenues in the Nerlovian adaptive acreage response model gave satisfactory results. Later, an area allocation scheme was formulated so that the individually estimated areas of different crops would add up to the exegenously specified total gross cropped area in the country. Finally, the estimated equations were all subjected to a validation exercise to judge how best they can be relied for incorporating them into large-scale system studies.

NOTES

1. See Krishnan (1965).
2. For example, see Cummings (1975).
3. See Behrman (1968) for a critical analysis of this model.
4. See Lipton (1966) for comments on this study.
5. Prior to this, we will also summarise our experience of estimating the traditional Nerlovian model.
6. When, to explore this problem, we extended the range of $\beta$ to 2.0, we did get interior estimates of $\beta$ for a number of crops.
7. See Box and Jenkins (1970) for a detailed discussion of the theory.
8. See Box and Jenkins (1970) for a detailed discussion of the theory.
9. We used an IMSL computer programming package for this purpose.
10. Johnston (1972): "Econometric Methods".

11. Malinvaud: "Statistical Methods of Econometrics".

12. In several other exercises of ours, indeed it has been so.

13. We made use of Morris Norman (IIASA 1977)'s "Software Package for Economic Modelling" for estimation purposes.

14. Hereafter, the significance is judged at 5% level.

15. We made use of Gunther Fischer (IIASA)'s computer programming package "Non-Linear Least Squares Estimation (NLSQ)" for our estimation purposes. The estimation results are shown in table 6.1.

# REFERENCES

Askari, H., and J.T. Cummings (1976) Agricultural supply response: a survey of the econometric evidence. Praeger Publishers.

Behrman, (1968) Supply response in underdeveloped agriculture: a case study of four major annual crops in Thailand 1937-1963. Amsterdam: North Holland.

Bhagwati and Chakravarty (1969) Contributions to Indian economic analysis: a survey. American Economic Review.

Box, G.E.P., and G.M. Jenkins (1970) Time Series Analysis: forecsasting and control. Holden-Day.

Cummings, J.T. (1975) The supply responsiveness of Indian farmers in the post-independence period. Indian Journal of Agricultural Economics.

Narain, D., (1965) The impact of price movements on areas under selected crops in India, 1900-1939. Cambridge University Press.

Fischer, F.M., and P. Temin (1970) Regional specialization and the supply of wheat in the United States, 1867-1914. Review of Economics and Statistics.

Government of India: Estimates of area and production of principal crops. Ministry of Food and Agriculture.

Government of India (1968) Indian crop calendar. Ministry of Food and Agriculture, Community Development and Cooperation.

Jaikrishna, and Rao, M.S.,(1967) Dynamics of acreage allocation for wheat in Uttar Pradesh. Indian Journal of Agricultural Economics.

Krishna, R., (1963) Farm supply response in India and Pakistan: a case study of the Punjab region. The Economic Journal.

Krishnan, T.N., (1965) The marketed surplus of foodgrains: is it inversely related to price? Economic and Political Weekly (Annual number).

Lipton, M., (1966) Should reasonable farmers respond to price changes? A review article in modern Asian Studies.

Madhavan, M.C., (1972) Acreage response of Indian farmers: a case study of Tamilnadu. Indian Journal of Agricultural Economics.

Maji, C.C., D. Jha, and L.S. Venkatraman (1971) Dynamic supply and demand models for better estimations and projections: an econometric study of major foodgrains in the Punjab region. Indian Journal of Agricultural Economics.

Nerlove, M., (1958) The dynamics of supply: estimation of farm supply response to price. Johns Hopkins.

Nerlove, M., (1971) Analysis of economic timeseries by Box-Jenkins and related technique. Report 7156, Centre for Mathematical Studies in Business and Economics, University of Chicago.

Nowshirvani, V.F., (1972) Land allocation under uncertainty in subsistence agriculture. Oxford Economic Papers.

Parikh, A., (1972) Market responsiveness of peasant cultivators: some evidence from Prewar India. Journal of Development Studies.

Parikh, K.S., (1977) A framework for an agricultural policy model for India. IIASA (RM-77-59).

Rao, M.S., and Jaikrishna (1965) Price expectation and acreage response for wheat in Uttar Pradesh. Indian Journal of Agricultural Economics.

Ray, S.K., (1977) Variations in crop output. Institute of Economic Growth.

Subbarao, K., (1969) Farm supply response: a case study of sugarcane in Andhra Pradesh. Indian Journal of Agricultural Economics.

Teekens, R., and R. Jansen, (1977) A note on the estimation of the parameters of a multiplicative allocation model. Report 7703/ES, Econometric Institute, Erasmus University, Rotterdam.

# APPENDIX A

Substitutable crops in India.

| Sl. No. | State | Name of the Crop |
|---|---|---|
| 1 | Andhra Pradesh | (Rice, Ragi, Mesta), (Jowar, Maize, Bajra), (Cotton, Groundnut, Sesamum), (Wheat, Gram). |
| 2 | Assam | (Rice, Jute), (Moong, Gram, Urad, Cotton, Wheat). |
| 3 | Bihar | (Ragi, Rice, Jute), (Wheat, Barley, Peas, Gram, Sugarcane). |
| 4 | Maharashtra | (Linseed, Wheat, Gram), (Sugarcane, Wheat, Gram), (Jowar, Bajra, Maize, Cotton). |
| 5 | Madhya Pradesh | (Linseed, Wheat, Gram), (Jowar, Bajra, Maize, Cotton). |
| 6 | Madras | (Rice, Ragi, Mesta), (Jowar, Maize, Bajra), (Cotton, Groundnut, Sesamum). |
| 7 | Mysore | (Rice, Ragi), (Jowar, Sugarcane), (Cotton, Groundnut), (Bajra, Maize). |
| 8 | Orissa | (Rice, Ragi, Jute). |

Substitutable crops in India.

| Sl. No. | State | Name of the Crop |
|---|---|---|
| 9 | Punjab | (Wheat, Barley, Gram, Peas), (Jowar, Bajra, Maize, Cotton, Sugarcane). |
| 10 | Rajasthan | (Jowar, Bajra, Maize, Pulses), (Wheat, Barley, Gram, Peas). |
| 11 | Uttar Pradesh | (Wheat, Barley, Gram, Peas), (Jowar, Bajra, Maize, Sugarcane). |
| 12 | West Bengal | (Autumn Rice, Jute), (Sugarcane, Jute), (Sugarcane, Rice). |
| 13 | Delhi | (Gram, Wheat), (Wheat, Barley), (Barley, Gram). |
| 14 | Himachal Pradesh | (Wheat, Barley), (Wheat, Gram), (Barley, Gram), (Wheat, Mustard), (Maize, Sesamum), (Maize, Pulses). |
| 15 | Manipur | (Wheat, Peas, Mustard), (Maize, Soya-bean, Sugarcane). |

## APPENDIX B: SOWING, HARVESTING AND PEAK MARKETING SEASONS OF PRINCIPAL CROPS--INDIA

| Season | Winter Rice | Autumn Rice | Summer Rice | Wheat | Jowar (Kharif) | Jowar (Rabi) | Bajra |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Sowing | Jun-Oct | Mar-Aug | Nov-Feb | Sep-Dec | Apr-Aug | Sep-Dec | Jun-Aug |
| Harvesting | Nov-Apr | Jun-Dec | Mar-Jun | Feb-May | Sep-Jan | Jan-Apr | Sep-Dec |
| Peak Marketing | Dec-May | Sep-Dec | Apr-Jul | Apr-Jun | Nov-Jan | Feb-Apr | Nov-Jan |

| Season | Maize (Kharif) | Maize (Rabi) | Ragi | Barley | Gram | Tur (Kharif) | Sugar-cane |
|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Sowing | Jun-Aug | Oct-Dec | May-Nov | Oct-Dec | Sep-Dec | May-Aug | Dec-May |
| Harvesting | Aug-Nov | Jan-Apr | Sep-Mar | Feb-May | Feb-May | Nov-Apr | Oct-Apr |
| Peak Marketing | Oct-Dec | Mar-Apr | Nov-Mar | Apr-Jun | Apr-Jun | Feb-Jun | Dec-Apr |

| Season | Tobacco | Ground-nut | Castor | Rape seed & Mustard | Linseed | Sesamum |
|---|---|---|---|---|---|---|
| | 16 | 17 | 18 | 19 | 20 | 21 |
| Sowing | Jul-Dec | May-Aug | Jun-Oct | Sep-Nov | Sep-Nov | May-Sep |
| Harvesting | Jan-May | Sep-Jan | Oct-Apr | Jan-Apr | Jan-May | Aug-Dec |
| Peak Marketing | Feb-Jun | Nov-Jan | Mar-Jun | Mar-May | Mar-Jun | Nov-Feb |

| Season | Sesamum (rabi) | Cotton | Jute | Sannbemp | Potato (Winter) | Potato (summer) |
|---|---|---|---|---|---|---|
| | 22 | 23 | 24 | 25 | 26 | 27 |
| Sowing | Dec-Feb | Mar-Sep | Feb-Jul | Apr-Aug | Aug-Dec | Feb-Jul |
| Harvesting | May-Aug | Sep-Apr | Jul-Nov | Sep-Jan | Jan-May | May-Dec |
| Peak Marketing | May-Aug | Nov-Mar | Aug-Jan | Dec-Feb | Feb-May | Oct-Mar |