Scenario Analysis of Indian Semi-Arid Tropical Crop Markets

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SCENARIO ANALYSIS OF INDIAN SEMI-ARID TROPICAL CROP MARKETS

ABSTRACT

An impact analysis of increase in ICRISAT mandate crop productivity and other policy changes on crop production, consumption, prices and farmer's income in the Semi-Arid Tropical regions of India is undertaken here by simulating hypothetical scenarios. A competitive equilibrium model of demand and supply for mandate (and their competing) crops incorporating contemporaneous and dynamic feedbacks is formulated for the above purpose. The reference point for all the scenarios is a base simulation covering the ten year period 1969-78. Certain trade assumptions based on relative crop shares in the all India production/consumption helped in tuning the base simulation to trace historical trends and turning points in the data.

The annual rainfall variable in the model when simulated for a drought situation produced meaningful reallocation of resources, although the timing rather than the total amount of rainfall is important in crop production. Due to a 10% rainfall shortage in one year there is an induced shift of resources away from water intensive crops like rice and wheat to the production of sorghum (2.7%) and other coarse-cereals (1.2%). In contrast, the production of pulses and oilseeds declined by 3.1% and 1% respectively. The prices in general behaved conversely. Due to adverse relative prices, the aggregate demand for superior cereals and other commodities declined. These effects, however, got absorbed overtime.

Sorghum productivity increase has the anticipated negative effect on the sorghum price in order that the increased sorghum production to be absorbed within the SAT region. An S-shaped increase in sorghum productivity of 25% spread over nine years resulted in output expansion of 33.1% and price decline of 12.7% for sorghum. On the average, sorghum producers have greater gross revenue since the increase in production more than compensated the decline in price. The larger sorghum production and lower sorghum price implied that the Indian SAT consumers of sorghum are better off due to this productivity increase. The reallocative effects of sorghum productivity increase are rather weak. For example, oilseeds substitute somewhat for sorghum in production and sorghum substitutes for superior cereals and other coarse cereals in consumption. Similarly, other changes in infrastructural facilities like road density, irrigation and investment resource like non-crop income caused diverse production patterns and allocation of available resources.
A major purpose of ICRISAT is to develop new technologies and procedures which will increase the productivity of the five mandate SAT crops (sorghum, pearl millet, pigeonpeas, chickpeas and groundnuts) under a variety of environmental conditions. But a productivity change for a particular crop may have important impacts not only on production of that crop, but also on its market price and on the income and therefore the expenditure of its producers. Moreover it may have impact on other crops by inducing shifts in land and other resources among crops and, through induced price changes of these other crops in addition to that in the price of the original crop, by inducing shifts in consumption patterns. Furthermore the productivity change for the original crop may induce shifts in demands for inputs like hired labor and fertilizers, with possible repercussions in their availabilities and prices. Finally, all of these changes do not necessarily occur in the crop year in which the original productivity change is introduced, but may occur with complex patterns of lags and feedbacks due to the time required for adjustment and formation of expected prices.

Such a process is complicated indeed. To understand it well requires good knowledge of the technical and behavioral considerations that underlie supply and demand, and how they interact over time. Such knowledge must include not only the directions of direct and induced responses, but also their magnitude and timing.

To help understand the nature of the impact of changes in SAT mandate crop productivity as well as of a number of other possible interesting changes some of which are noted below, we have been developing a model of supply and demand in SAT agriculture. This model can be used to simulate alternative hypothetical scenarios and thereby to investigate the nature of effects induced by ICRISAT mandate crop productivity changes and other changes. In this paper we present the critical elements of the phase.

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version of this model and explore several illustrative scenarios, using SAT India as an empirical example. Thereby we hope both to provide an illustration of the uses and limitations of this tool and to solicit comments and suggestions regarding the ongoing development of this model.

Section 1 briefly presents the structure of the model and describes the empirical bases for its parameterization. Section 2 gives our base simulations. Section 3 considers simulations of system-wide responses to a variety of scenarios of changes in productivity, highway infrastructure, total consumption expenditure, rainfall, irrigation, inventory behavior and price policy.

**Section 1. Supply and Demand Market Model for ICRISAT Mandate Crops in SAT India**

Modelling by definition requires abstraction from the complexity of reality in order to focus on the essential elements of the phenomena under investigation. In empirical application often further abstractions of theoretical models are required due to unavailability of certain data. In our modelling we work with basic supply and demand functions for SAT products which have been estimated by ICRISAT staff working with various collaborators.

**Supply:** We use estimates for the supply side based on the careful study of systems of output supply and factor demand for SAT India by Bapna, Binswanger and Quizon (hereafter BBQ). We summarize their approach and estimates and our use of them. For more details concerning these estimates see BBQ.

The data base for these estimates was assembled for 73 districts in the four states of Tamil Nadu, Karnataka, Andhra Pradesh and Madhya Pradesh for the years 1956/57 through 1974/75 by ICRISAT. These data cover 22 principal crops, including all five of the ICRISAT mandate crops:

- **Two superior cereals:** rice, wheat
- **Six coarse cereals:** sorghum (jowar), pearl millet (bajra), maize, finger millet (ragi), kudon and kutki (kodo and barnyard millets), and other minor millets.
- **Six pulses:** chickpea (bengal gram), pigeonpea (tur or red gram), green gram (mung), black gram (urad), horse-gram (kulthi), and other pulses.
- **Four oilseeds:** groundnuts, sesame, castorbean, linseed.
- **Four other crops:** sugarcane, cotton, tobacco, chillies.

The included states account for the following percentages of Indian output and acreage of the major crops that we consider: Wheat (10.8, 17.5), rice (15.6, 14.1), sorghum (36.7, 42.0), other cereals (30.2, 22.4), pulses (24.3, 31.0), oil-seeds (37.4, 35.0) and other crops (27.1, 28.2).
For some purposes the districts are aggregated into 17 agroclimatic subregions on the basis of average rainfall, percent of gross cropped area irrigated and cropping pattern of dominant crops.

These data were used to estimate six output supply-factor demand systems, with the differences among them depending on the extent of geographical coverage (for example estimates were made separately for those areas in which rice and for those in which wheat is the dominant superior cereal) and the level of aggregation of crops. For our Phase I model we use the BBQ System 'A' estimates, which cover their entire SAT region with six output commodities:

1. Wheat and rice are aggregated into superior cereals since one or the other are produced in each of their agroclimatic subregions.

2. Sorghum is grown in virtually all subregions and therefore is treated as a separate commodity.

3. The other five coarse cereals each are cultivated much less broadly and therefore are aggregated into other coarse cereals.

4. The pulses are treated as a single aggregate for the same reason.

5. Oilseeds are treated as a single aggregate for the same reason.

6. The other crops are the four noted above in this category. They share the characteristics of requiring relatively high levels of purchased inputs in comparison to most food crops, being produced largely by market-oriented producers, and (except for chillies) largely being processed in separate processing industries before being consumed.

The only variable input for which data permitted the estimation of a separate input demand system is fertilizers, as measured in tons of nutrients of N, P, K, and S. Labor demand is not estimated due to a lack of data, but the effect of wage rates (as represented by daily male wage rates for standard eight hour days) is incorporated. Consistent data could not be found, however, for the quantities or the prices of other standard inputs (e.g., bullocks). Five additional variables also were included:

1. Rainfall.

2. Extent of use of high yielding varieties of rice, wheat, sorghum, pearl millet and maize as proportion of total cropped area.

3. Road density in km/10km^2 which BBQ suggest is their best measure of market access.

4. Regulated market density in number/10000km^2 which BBQ suggest measures government assistance to the marketing process (and not market access since there are a number of unregulated markets).

5. Extent of irrigation as proportion of cropped area.
The basic output supply-factor demand model for one observation can be represented in vector notation as:

\[ S = f(P^*, X, U) \]

Where \( S \) is a seven-element vector of quantities, including the output supplies of each of the six commodities defined above and the input demanded of fertilizer.

\( P \) is a six-element vector of expected prices at the time of production decisions with one element corresponding to each of the first six elements of \( S \).

\( X \) is a seven-element vector including fertilizer price, wage rate and the five additional variables noted above.

\( U \) is a seven-element vector of stochastic terms to represent unobserved factors, one for each of the elements of \( S \).

An equivalent representation of the \( i^{th} \) crop supply (or factor demand), which we approximate below, is the growth rate form:

\[ \dot{S}_i = \sum_{j=1}^{6} E_{S_i, P_j} \dot{P}_j + \sum_{j=1}^{6} E_{S_i, X_j} \dot{X}_j + E_{S_i, U_i} \dot{U}_i \]

where the standard convention is used that a dot above a variable means the growth rate ($\dot{Z} = \Delta Z / Z$);

\( E_{YZ} \) is the elasticity of \( Y \) with respect to \( Z \) (= \( (\Delta Y / Y) / (\Delta Z / Z) \)); and subscripts \( i \) and \( j \) refer to elements in the indicated vector.

This relation states that the growth rate of the \( i^{th} \) crop's output supply (or input factor demand) is a weighted average of the growth rates of all expected prices \( (\dot{P}_j^*) \), all of the additional variables \( (\dot{X}_j) \), and the disturbance \( (\dot{U}_i) \), with the weights being the respective output (or factor input) elasticities.

The elasticities incorporate the underlying technological and behavioral responses to changes in various expected prices and other variables. In general, the elasticities are not constant, but depend on the overall configuration of output supplies and input demand, which in turn depend on the overall configuration of expected prices and other variables.

BBQ place great emphasis on the systemic characteristic of relations (1) and (2). That is, they highlight the interactions among the various crop output supplies and input demands that are inherent in these relations since the output of any one crop (or the demand for any one input) depends on all expected price ratios given that substitution of land, labor, and other inputs may occur among the crops. The systemic approach (as opposed to the more common alternative of estimating relations for each crop separately) has the advantage of assuring
consistency of the estimated substitution possibilities (i.e., the implied substitution between crop i and crop j is the same whether viewed from the point of view of crop i or of crop j), of allowing testing of whether or not the estimated description of behavior is consistent with underlying profit (or net revenue) maximization by farmers, and of allowing cross-crops (or input) associations in the unobserved disturbance terms. BBQ also "gained the impression that elasticities of individual commodities...estimated in a system context are more stable and more in line with a priori expectations than single equation estimates." (p.4).

These advantages over the usual single-equation approach seem to be quite considerable. But, as always, they are purchased at a cost. In this case the cost relates to the added data requirements (since observations on each commodity are required for each geographical unit in each time period), the related greater aggregation so that in fact each commodity is produced in each geographic unit in each time period (which explains why BBQ aggregate to the six commodities above to insure some production of each commodity in each observation even though every crop is not produced in every geographical unit), the greater computational complexities and costs, and the need to impose some uniformities that may not exist in reality (e.g., they impose the same lag structure on all past prices in forming their expected prices, but there may be asymmetries among crops in adjustment possibilities so that actual lags are different). Though these costs are not negligible, they are outweighed from our viewpoint by the advantages of the systemic approach (particularly since not we, but BBQ, have borne that data collection and computational costs).

To estimate the parameters of relation (1) which underlie the elasticities in relation (2) some specific functional forms must be used for relation (1). BBQ derive functional forms from generalized Leontief and normalized quadratic profit functions. Also some explicit assumptions about expected price formulation is required. After experiments with various lag structures, BBQ adopted the following uniform specification for all expected crop prices:

\[
(3) \quad P_t^* = 0.71 P_{t,-1} + 0.29 P_{t,-2}
\]

Where \( P_t \) is the actual price of the \( t \)th crop (or input) and the subscripts -1 and -2 refer to lags of one and two years, respectively.

Finally, an assumption is required about the nature of the disturbance terms, \( U \). BBQ assume that the disturbance for the \( t \)th crop (input) in the \( t \) period in a particular district can be decomposed into three independent, normally-distributed components: one which is region specific, a second which is time dependent, and a third which is independent of the disturbances for other time periods, regions, and crops.

Under these specific assumptions about the functional form of relation (1), BBQ obtain system estimates of the parameters which underlie the elasticities in relation (2) on the basis of pooled time-series (17 years, after 2 are lost due to the lag structure in relation 3) and cross-section (73 districts, aggregated into 13 regions) data. The combination of cross-section and time-series data permit added precision in the estimates.
<table>
<thead>
<tr>
<th>Output supply elasticities for:</th>
<th>Superior Sorghum</th>
<th>Other coarse cereals</th>
<th>Oilseeds</th>
<th>Other crops</th>
<th>Fertilizer</th>
<th>Labor input demand elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output supply elasticities for: Superior Sorghum</td>
<td>0.048</td>
<td>0.081</td>
<td>0.051</td>
<td>0.028</td>
<td>0.120</td>
<td>0.300</td>
</tr>
<tr>
<td>Other coarse cereals</td>
<td>0.020</td>
<td>0.054</td>
<td>0.088</td>
<td>0.082</td>
<td>0.312</td>
<td>0.174</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>-0.247</td>
<td>-0.275</td>
<td>-0.247</td>
<td>-0.118</td>
<td>-0.219</td>
<td>-0.407</td>
</tr>
<tr>
<td>Other crops</td>
<td>-0.304</td>
<td>-0.329</td>
<td>-0.132</td>
<td>-0.092</td>
<td>-0.062</td>
<td>-0.097</td>
</tr>
</tbody>
</table>

Table 1: Revised Crop Output Supply and Fertilizer and Labor Input Demand Elasticities for SA India

Expected prices of:

<table>
<thead>
<tr>
<th>Superior Sorghum</th>
<th>Other coarse cereals</th>
<th>Oilseeds</th>
<th>Other crops</th>
<th>Fertilizer</th>
<th>Labor input demand elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior Sorghum</td>
<td>0.129</td>
<td>0.189</td>
<td>0.249</td>
<td>0.312</td>
<td>0.300</td>
</tr>
<tr>
<td>Other coarse cereals</td>
<td>-0.200</td>
<td>-0.113</td>
<td>-0.078</td>
<td>-0.032</td>
<td>-0.223</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>-0.130</td>
<td>-0.239</td>
<td>-0.118</td>
<td>-0.092</td>
<td>-0.097</td>
</tr>
<tr>
<td>Other crops</td>
<td>-0.304</td>
<td>-0.329</td>
<td>-0.132</td>
<td>-0.092</td>
<td>-0.097</td>
</tr>
</tbody>
</table>

Source: Normalized quadratic profit function estimates, evaluated at point of sample means, for expected prices from Table 5. Since the original estimates given in Table 5 do not satisfy the convexity conditions, we adopted an iterative trial and error procedure to arrive at the above convex estimates. N.A. = Not available.
Table 1 summarizes the implied elasticities at the points of sample means for the normalized quadratic system.\(^1,2\) We use these elasticities for our Phase I simulation model under the assumption that the elasticities in relation (2) can be considered to be approximately constant.\(^3\) The elasticities imply some interesting patterns: own-price elasticities range from 0.16 to 0.87, which indicates fairly substantial price responsiveness in this fairly poor area, consistent with the emphasis of Schultz and others, some of the cross-price elasticities have absolute values in the range of 0.2 to 0.3, which suggests the importance of systemic effects; increased wage rates reduce production of sorghum and pulses; increased rain causes a shift from sorghum to pulses and superior cereals; spread of high-yielding varieties causes a shift from sorghum and other coarse cereals to superior cereals and the other crop category and increased fertilizer demand; increased road density causes a shift from pulses and oilseeds to superior cereals and the other coarse grain category and an expansion of fertilizer demand presumably all due to the improved market access; and increased irrigation causes expansion of superior cereals and oilseeds with no significant impact on other crops nor on fertilizer demand.

**Demand:** We use estimates for the demand side based on the careful study of systems of demand for low-income rural Indians by Murty and Radhakrishna (MR). These estimates have parallel systematic advantages (and costs) as do the supply estimates described above. In addition they have advantages over available alternatives of permitting focus on a rural income group at approximately the SAT level (see below), of satisfying the convexity conditions implied by theory, of permitting approximately a comparable level of aggregation as on the supply side, and of being very familiar to one of the present authors. For more details concerning these estimates see Murty, MR.\(^4,5\)

The data base for the Murty, MR estimates is a pooled time series of cross-section estimates from the National Sample Survey Organization (NSSO) for 1950-51 through 1970-71 (rounds 2 through 25). These data permit a hierarchical approach in which systems of demand equations for more aggregate commodities first are estimated, and then these broader aggregates are decomposed into components on a level of aggregation approximately comparable to those used in subsequent phases of our model work we will use the underlying structural relations which imply changing elasticities, but for simplicity in the present case we focus on the elasticities at the points of sample means.

\(^1\) We prefer the normalized quadratic estimates over the generalized Leontief form because in the latter the own-price elasticities are calculated as residuals and therefore incorporate the total effects of all biases in the system estimates. See BBQ, pp. 11-12.

\(^2\) The estimates in Table 5 of BBQ do not satisfy the convexity conditions of net revenue maximization. Since these conditions are inequality restrictions, standard statistical packages do not allow for their imposition. It is possible, however, to impose these conditions approximately by trial and error methods. We adopted such a procedure to arrive at the estimates given in Table 1.

\(^3\) An alternative set of estimates also developed by a former ICRISAT staff member and collaborator is available in Swamy and Binswanger. In future work we may explore the sensitivity of the simulations to use of these alternative estimates.

\(^4\) Work is still underway by Murty. Future extensions may include estimates based solely on the SAT area.
in the supply estimates above. 6

1. Superior cereals
2. Sorghum
3. Other coarse cereals
4. Pulses
5. Edible oils
6. Other items

The differences between this disaggregation and that used for supply are three. First, the other category is much different since it includes items like clothing, fuel and light, and other nonfood goods. Therefore, we don't assume that the sixth category of supply equals the sixth category of demand to determine an endogenous price below. Second, the fifth category on the demand side is the processed counterpart to the fifth category on the supply side with the extent of off-farm processing probably considerably greater in the case of this commodity than for the first four commodities. Third, in the Murty demand system chickpeas are included in category three instead of in category four as in the BBQ supply system.

The basic demand or expenditure system model for one observation can be represented in vector notation as:

\[ D = g(P_d, Y, V) \]

where 
- \( D \) is a six-element vector of quantities demanded for the commodities defined above.
- \( P_d \) is a six-element vector of prices faced by consumers with one element corresponding to each element of \( D \).
- \( Y \) is total expenditure.
- \( V \) is a six-element vector of stochastic terms to represent unobserved factors, one for each of the elements of \( D \).

An equivalent representation for the \( i \)th commodity demand, which we approximate below, is the growth rate form:

\[ \dot{D}_i = \sum_{j=1}^{6} E_{D_1} p_{d}^{j} p_{i}^{d} + E_{D_1} Y \ddot{Y} + E_{D_i} V_i \ddot{V}_i \]

where the conventions defined below for relation (2) are used.

This relation states that the growth rate of the demand for the \( i \)th commodity is a weighted average of the growth rates of all prices faced by demanders \((P_d^j)\), of expenditure \((\dot{Y})\), and of the disturbance \((\ddot{V}_i)\), with the weights being the respective demand elasticities. These elasticities incorporate the underlying behavioral responses and the aggregation across individual households. In general the elasticities are not constant but depend upon the overall configuration of market prices, expenditure, and the distribution of purchasing

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6 Actually Murty has 16 commodities but we aggregate them to make them as comparable as possible with the first five categories of BBQ and include all of the other items in Murty's study in demand category six.
power. 7 To estimate the parameters of relation (4) which underlie the elasticities in relation (5), some specific functional form must be used. MR utilize the Hasse generalization of the linear expenditure system which allows nonadditivity in the underlying utility function. 8 In order to overcome the linear expenditure effects implied by this model, they subdivide the sample into five (deflated or real) expenditure groups for rural areas and five for urban areas. They allow for cross-equation correlations in the elements of the disturbance vector (V) by using a generalized-least-squares estimator. Under these assumptions, MR obtain maximum-likelihood estimates of relation (4) for each of the 10 real expenditure groups using pooled time series-cross section NSSO data.

For the Phase I model we utilize the MR estimates for the second lowest expenditure category in the rural sample under the assumption that these best approximate expenditure levels for the commodities of concern for SAT India. 9 We also assume that the elasticities calculated at the sample means for this expenditure group can be considered approximately constant. 10 Table 2 gives these estimated elasticities, which have several interesting patterns.

First, all of the own-price elasticities are negative, as theory suggests should be the case for normal goods. They range from -.62 for edible oils to -1.92 for sorghum.

Second, there are some fairly large cross-price effects, both positive and negative, but primarily involving superior cereals. For this reason using a system of demand relations is important for analysis of various scenarios. For example, a 10% increase in the price of superior cereals implies increases of 6% and 8%, respectively, in quantities demanded of other coarse cereals and of sorghum, and decreases of 3% for edible oils and of 2% for both pulses and all other commodities. (The only other cross-price elasticities as large in absolute value as the smallest of these are those between sorghum and other coarse cereals.)

Third, the expenditure elasticities vary somewhat with those for other coarse cereals (.69) and for superior cereals (.93) being relatively inelastic. In contrast, the expenditure elasticities for the other four categories all are slightly above unity (1.01 to 1.24). Thus, as income and expenditure increases, ceteris paribus, there is the well-known shift in expenditure shares away from other coarse cereals and to a lesser extent from superior cereals to the other food and nonfood categories.

7 MR show how income shifts can alter the aggregate elasticities based on their estimates for five expenditure categories for rural India and five categories for urban India.

8 To satisfy the convexity conditions, MR impose the restriction that nonfood groups are additively separable, thus reducing this part of the model to a linear expenditure system.

9 This expenditure group is 8 to 13 in 1961-62 rupees per capita per month.

10 In subsequent phases of our model work we will use the underlying structural estimates, which imply changing elasticities, and the estimates from other expenditure groups.
Table 2. Commodity Demand Elasticities for Rural Indian Low-expenditure Groups

<table>
<thead>
<tr>
<th>Demand Elasticity of</th>
<th>Superior cereals</th>
<th>Sorghum</th>
<th>Other cereals</th>
<th>Pulses</th>
<th>Edible oils</th>
<th>Other commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>With respect to price of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior cereals</td>
<td>-1.204</td>
<td>0.829</td>
<td>0.563</td>
<td>-0.193</td>
<td>-0.331</td>
<td>-0.165</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.204</td>
<td>-1.917</td>
<td>0.151</td>
<td>-0.045</td>
<td>-0.077</td>
<td>-0.039</td>
</tr>
<tr>
<td>Other cereals</td>
<td>0.188</td>
<td>0.205</td>
<td>-1.315</td>
<td>-0.084</td>
<td>-0.144</td>
<td>-0.072</td>
</tr>
<tr>
<td>Pulses</td>
<td>-0.011</td>
<td>-0.012</td>
<td>-0.008</td>
<td>-0.920</td>
<td>0.042</td>
<td>0.003</td>
</tr>
<tr>
<td>Edible oils</td>
<td>-0.024</td>
<td>-0.027</td>
<td>-0.018</td>
<td>0.035</td>
<td>-0.619</td>
<td>-0.001</td>
</tr>
<tr>
<td>Other commodities</td>
<td>-0.081</td>
<td>-0.088</td>
<td>-0.060</td>
<td>-0.032</td>
<td>0.005</td>
<td>-0.879</td>
</tr>
<tr>
<td>With respect to total expenditure</td>
<td>0.928</td>
<td>1.010</td>
<td>0.687</td>
<td>1.240</td>
<td>1.123</td>
<td>1.153</td>
</tr>
</tbody>
</table>

Source: Nassa expenditure system estimates for second lowest expenditure class in work summarized in MR.
The Production Equals Absorption Identity: For the \( i \)th commodity in SAT agriculture the total supply is SAT production \( (S_i) \) plus net imports into SAT \( (M_i) \). The total absorption includes demands for current human consumption \( (D_i) \) for current livestock consumption \( (L_i) \), for seed reserves \( (R_i) \), and for changes in inventories held by producers \( (\Delta I_i^P) \), consumers \( (\Delta I_i^C) \), market wholesalers and retailers \( (\Delta I_i^R) \) and public authorities \( (\Delta I_i^A) \). In addition, there is significant wastage \( (W_i) \), including spoilage and loss to insects and other animals. Total production equals total absorption:

\[
S_i + M_i = D_i + L_i + R_i + \Delta I_i^P + \Delta I_i^C + \Delta I_i^m + \Delta I_i^g + W_i
\]

In principle, all of the components of supply and absorption indicated in relation (6) may be responsive to actual and/or expected prices of SAT commodities. If their responses differ, the composition of both supply and demand may change as prices (or expected prices) change.

In practice, unfortunately, data are not available with which we can estimate the market responsiveness of most of these components. Therefore, we assume for our basic Phase I simulation model that the sum of net exports, livestock use, seed reserves, producer stock changes, and wastage is proportional to supply for sorghum, other coarse cereals and pulses:

\[
aS_i = L_i + R_i + \Delta I_i^P + W_i - M_i
\]

Likewise, for these commodity groups, we assume that the sum of other (i.e., nonproducer) inventory changes is proportional to demand:

\[
bD_i = \Delta I_i^C + \Delta I_i^m + \Delta I_i^g
\]

under these assumptions, relation (6) may be rewritten as:

\[
(6A) \quad (1-a)S_i = (1+b)D_i
\]

so that:

\[
(6B) \quad S_i = D_i
\]

\[11\] Net imports of course, are negative if exports exceed imports.
Relation (6B) can be utilized with relation (2) substituted in the left side and with relation (5) substituted in the right side, which ties the production equals absorption identity of relation (6) directly back to the discussion above about supply and demand systems. Three points about our use of relation (6B) must be emphasized.

First, we use relation (6B) as the basis for our basic simulation in the Phase I model because we are unable to observe most of the other quantities in the production equals absorption identity of relation (6). However, one of the beauties of the simulation approach is that, although we cannot observe these items, we can explore with simulations the impact of nonproportional behavior in them. For example, suppose - in contrast to relation (8) - that stocks are accumulated by market wholesalers and retailers more than proportionately due to speculative behavior. Say, for example, that this extra accumulation equals 10% of total SAT supply in a given year. We can explore the impact of such behavior on prices, current demand, and future supplies by modifying (6B) so that:

\[(6C) \quad \hat{s}_1 - .10 = \hat{d}_1\]

Likewise, the effects of an increase of 1% in supplies available for current consumption from above-normal government stockpile releases, added imports etc., can be investigated by using:

\[(6D) \quad \hat{s}_1 + .01 = \hat{d}_1\]

Second, one other advantage of working from the rate of growth form of the production equals absorption identity in relation (6B) (or variants thereof like 6C or 6D) is that we can easily combine supply and demand systems estimated for somewhat different geographical areas. For example, the BBQ supply estimates and the MR demand estimates are based on overlapping, but not identical regions. For the Phase I model we resolve this geographical discrepancy by using the BBQ quantity data for the SAT region and using relations (5) and (6B) to generate changes in demand from a base proportional to the BBQ quantity data.

Third, the assumption that net imports are proportional to supplies probably is a palatable approximation for sorghum, other cereals and pulses. In these cases, for the most part, net trade between SAT India and the rest of
India is fairly small relative to SAT production because of transportation and marketing costs, aggravated at times by government food zone policies and other regulations. Raju and von Oppen, however, suggest that the pulse market is relatively well integrated within India than others have claimed. And, of course, variations from this assumption can be explored as noted in the previous paragraph, or by assuming integration into the larger Indian market as for the other commodities as is discussed in the next paragraph.

For the other commodity supplies or demands in the model -- superior cereals supply and demand, oilseed supply, the other crop supply category, fertilizer demand, edible oil demand and the other commodity demand category -- in our simulations in Sections 2 and 3 we do not assume that SAT supplies are proportional to SAT demands as in relation (6B). We do not do so because in these cases, integration into the larger Indian market and/or government policies (particularly for fertilizer) mean that net imports are relatively large and variable in comparison to SAT production. In all but one of these cases we assume that prices are set in the larger India market outside of SAT or by government policies, with behavior in SAT responding to such prices. Thus we can explore, for example, the effects of a policy-induced change in the price of fertilizer on fertilizer use, crop production, and commodity consumption within SAT. Of course, the demand for fertilizer depends not only on the fertilizer price but on all the prices and other variables in the supply and demand systems.

In these cases the prices are fixed independent of SAT demands and supplies, because SAT quantities are quite small in the overall India market. For oilseeds - edible oils, however, SAT production is a larger share of the Indian total (about 45% in 1978). In this case, therefore, we make intermediate assumptions between the extremes of prices being determined completely within SAT (as for sorghum, other cereals and pulses) and prices being determined entirely outside of SAT (as for all remaining categories). The intermediate assumption is that the price is an inverse function of SAT quantity produced along a fairly flat price-quantity locus that reflects explicitly the SAT production share and the total Indian demand elasticity and the non-SAT supply elasticity. By differentiation of the identity that SAT plus non SAT supply equals total Indian demand, in other words, we obtain:

\[ E_{XP} = \delta r E_{D\text{r}P} - \delta X E_{S\text{r}P} \]

where the superscript \( r \) refers to the rest of India and \( X \) is exports from SAT to the rest of India.

Supply and Demand Price Relations: We have discussed how prices are determined outside of the Phase I model for superior grains, the other crops supply category, fertilizers, and the other commodities demand category. For the commodities on the supply side, in addition, there are expected prices \( P_i^a \) based on actual supply prices \( P_i \) as indicated in relation (3) and prices which consumers pay
on the demand side \( (P^d_i) \). The prices which consumers pay differ from those which farmers receive due to transportation, marketing, and processing costs \( (m_i) \), which differ from crop to crop:

\[
(10) \quad P^d_i = m_i P_i
\]

For our Phase I model we assume that these factors of proportionality are constant for each commodity \( \text{(not across commodities)} \)\(^\text{12} \) so that:

\[
(10A) \quad P^d_i = P_i
\]

With the added assumption that the prices of sorghum, other grains and pulses adjust within each year to clear approximately the individual markets, the Phase I model solves for their prices as follows. In a given year the expected farm prices are based on known previous year prices as given by relation (3). These expected prices, together with the other given variables in relation (2), determine the rates of growth of supplies of each of the commodities through relations (2). This fixes for that year the left side of relations (6B). By substituting relations (10A), into the rate of growth in demand in relations (5) and substituting the resulting relations into the right side of relations (10A), a system of expressions is obtained in which the rates of change of the prices of these three commodities and the quantities demanded of the other three demand categories are the only unknowns. This system can be solved for these prices and demand quantities. In this process current quantities supplied are given by responses to expected prices based on past prices, and current demands and current prices adjust for sorghum, other grains and pulses so that the rates of growth in these supplies equal those for these demands.

**Producer Revenue - Demander Expenditure Linkage:** A characteristic which distinguishes SAT agriculture from more-commercialized agriculture is that a substantial part of production is consumed by the farmers themselves. This implies an additional link between supply and demand beyond those through market prices since the total expenditure of demanders depends in considerable part on the revenues of producers. To capture this link we posit that total expenditures in the demand system depend on the weighted sum of the value of SAT production of the six supply commodities in the BBQ supply system \( (ES_i P_i) \) minus expenditures on fertilizer \( (S_7 P_7) \) plus other net expenditures \( (Y_0) \) which are independent of price and quantity movements for the commodities of concern.\(^\text{13} \)

\[
(11) \quad Y = c (\Sigma S_i P_i - S_7 P_7) + Y_0
\]

---

\(^{12}\) In subsequent work we may explore if these price differentials are related to changing transportation and market systems, interest charges, fuel costs, etc. over time.

\(^{13}\) Note that we value all production at market prices even though some of it is consumed on the farm without entering the market. The question of whether all or only the marketed proportion of production should be valued at market prices underlay a debate of some years ago regarding indirect measures of the price elasticity of the marketed surplus between Krishna and Behrman 1966.
The components of $Y$ may include some components of both farm and nonfarm net income generation and savings activity. But a substantial proportion of SAT economic activity may be related to the value of production of the farm commodities through the impact on related service and transport activities, which implies a value of $c$ greater than one. On the other hand, the first rightside expression in relation (10) is an overstatement of expenditure from SAT agricultural production to the extent that other nonfertilizer inputs and savings are not deducted from the gross value of production, which implies a value of $c$ below one, ceteris paribus. We use a base value of $C = 0.6$, but explore the sensitivity of our results to changes in this value.¹⁴

**Section 2. The Simulation Process and the Base Simulation**

We now turn to some basic nonstochastic simulations to illustrate some of the features of the Phase I model prior to the exploration of various scenarios in the next section. By way of introduction we first briefly summarize the functioning of the model and the simulation procedure, and then discuss the base simulation.

**Model Summary:** The model of the previous section can be summarized briefly as follows. In a given year there is an exogenous block of variables, two recursive blocks and a simultaneous block:

**Exogenous Block:** The exogenous variables include five prices (i.e., for fertilizers, labor, superior cereals, other commodities supplied, and other commodities demanded), the other five variables that enter into the supply system (i.e., rain, high yielding varieties, road density, regulated market density and irrigation), the exogenous part of expenditure ($Y₀$), and the values of the disturbance terms in $U$ and $V$ (all set equal to their mean values of zero for nonstochastic simulations). In addition all of the elasticities in relations (2) and (5) are assumed to be given by the values in Tables 1 and 2, and $c$ in relation (11) is set equal to 0.6.

**Recursive Block 1:** The current expected prices for the 6 output commodities supplied ($P₁^*$) are determined from lagged farm prices ($P₁,-1, P₁,-2$) as indicated in relation (3).

¹⁴ Estimating the empirical value of $c$ is not easy because of possible SAT macroeconomic multiplier effects, etc. We may be able to estimate $c$ more satisfactorily, nevertheless, in future work.
Recursive Block 2: Given the current quantities supplied, and exogenous prices (for superior cereals, other commodities demanded, and fertilizer), relations (5), (6B), (9) and (11) determine simultaneously the current endogenous prices (for sorghum, other grains, oilseeds-edible oils, and pulses), endogenous demand-quantities (for superior cereals, oilseeds-edible oils, and the other demand category), and total expenditures on all consumption (Y).

Given the results for one period, the model can be solved for subsequent periods, using lagged prices from the previous period solutions for the next year's Recursive Block 1, etc.

Model Solution: The Phase I model is quite simple in structure, with the variables entering linearly. Therefore, even the most complicated part, the Simultaneous Block, could be solved for endogenous prices and quantities explicitly by inverting an 8 x 8 parameter matrix. However, instead we use an iterative Gauss-Seidel procedure since future model phases will have nonlinearities, the algorithm input is straightforward which lessens the possibility of programming error, the algorithm is quite quick, and the output permits clear numerical and graphical interpretation of the simulation results.15

Base Simulation: The reference point for all of the scenarios which we consider in Section 3 is a base simulation in which all endogenous variables are solution values given the actual values for exogenous variables. That is, the endogenous variables are those values which are consistent with the actual exogenous values and the structure of the model given zero values for all of the stochastic disturbances (U in relation 1 and V in relation 4).16 This is a more useful reference point than would be actual values for the endogenous

15 The simulation program was written originally by Morris Norman at the University of Pennsylvania. It has been tested extensively and used for a wide variety of problems (e.g., exploring macroeconomic and foreign sector policies in a developing economy in Behrman 1976 and 1976b, Investigating the UNCTAD international commodity program and the impact of commodity fluctuations on developing countries in Behrman 1977a and Adams and Behrman, and studying the impact of human capital investments and demographic changes on income distribution in a developing country in Behrman, Wolfe, and Blau and Wolfe, Behrman and Blau).

16 Likewise, for lagged endogenous supply quantities, instead of using the actual values for the base simulation, we use the calibrated trend values so that the growth rates in relation (2) are initiated from the presimulation period trend line, without contamination due to nonzero stochastic values in the presimulation period.
variables because it makes clear the systematic impact of hypothesized changes without confusing impacts of stochastic terms.

The base simulation is a ten-year dynamic simulation in which, within the simulation period, simulated values of lagged endogenous variables are used instead of actual values. These lagged simulated values are one of the two major mechanisms which link impacts of hypothetical exogenous changes across periods in a dynamic fashion through the lagged values to which the growth rates in relations (2) and (5) are applied to obtain the levels of endogenous variables for the current simulation period. The other major dynamic mechanism, of course, is through the endogenous expected price generating mechanism in relation (3). The use of a decade simulation period allows substantial time for the dynamic effects of initial exogenous changes to work their way through the system. The use of such a long simulation period also permits exploration of whether or not there is error build up in the model.

We now turn to the base simulation values. The first three columns in Table 3 give some summary measures of the goodness of fit of the base simulation: mean absolute percentage errors (MAPE) for 1969-73 and for 1969-78 and root mean percentage errors (RMPE) for 1969-1978.

The goodness-of-fit statistics for the entire decade in Table 3 suggest that the model traces better the actual experience for SAT quantities supplied than for SAT prices (though pulses are an exception to this pattern). This is an expected outcome, given that within a period for the relevant commodities supplies are completely price inelastic, so all of the adjustment to short-run equilibrium must be in prices along the demand curve to the recursively-set quantities supplied.

The goodness-of-fit statistics also are relatively high for fertilizer input demands and superior cereals quantity demanded. They are relatively small for labor input demanded, the quantity demanded for the other item category, and total consumer expenditure. The low value for labor input demands reflects the very low labor input demand elasticities in the last column of Table 1, which result in little variation in labor demands no matter what is the magnitude of discrepancies between other actual and simulated endogenous variables. The low value for total consumer expenditure is due to a combination of some of the errors in the components of this variable canceling out in the constructed aggregate (particularly high prices for low quantities supplied and vice versa) and of there being an exogenous component \( Y_0 \) in relation (11). The low error for the other consumer demand component reflects the small error in total expenditure, in combination with the exogenously-fixed value of the other major determinant of this demand variable--the own price (given the small cross-price elasticities for this category in Table 2).

Remember that the prices for superior cereals and the sixth demand category are set exogenously in the rest of India.
The MAPE and RMPE also are relatively large in comparison with those reported in many other studies. This may reflect several factors. First, the dynamic simulation period of a decade is fairly long and there is significant error build up. This can be seen in that the MAPE's generally are smaller (and often substantially so) for the first five years than for the whole decade (compare columns 1 and 2 in Table 3). In other words, as is almost always the case for such models, there is more success in tracing out experience in the short and medium runs than for the longer run.

Though the MAPE's for the first quinquennium are lower than for the decade, they still are relatively large. This may be because of the great volatility of SAT agriculture despite the attempt to incorporate weather conditions in the supply estimates (i.e., $U$ is relatively large in relation 1). To the extent that this is the case, the base simulation just reflects the well-known environmental variability in SAT agriculture and the difficulty of summarizing that variability in manageable weather indices for econometric estimates.

Another contributing factor may be that the systems estimates do not assume that the mean error for each endogenous variable is zero over the estimation period (as do ordinary-least-squares single-equation estimates), so in some cases the base simulated values are systematically too high or too low. To the extent that this possible system feature underlies the relatively large errors, some questions are raised about the stochastic specification of the system estimates and the uncorrected models may under (over) estimate systematically some endogenous variables. Nevertheless, the model may serve well (and possibly better than single-equation estimates which would trace the sample experience better, but not capture the system features as well) for exploring the impact of hypothesized exogenous changes as in Section 3.

In addition to goodness-of-fit measures based on errors, it is useful to ask how well the model traces turning points in Indian SAT agricultural experience over the simulation decade. The summary answer to this question is: fairly well, especially given the great volatility in Indian SAT. There are some failures (e.g., on the quantity side, the 1971 trough for sorghum, the 1975 peak for pulses, the 1976 trough for oilseeds) but these tend to be concentrated in the latter half of the simulation period after there is more substantial error build up. All in all, there is fairly considerable success in identifying such turning points.

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18 The single exception to this statement is for the quantity supplied of other crops.

19 The sample and simulation period are not identical, but they overlap considerably.
All of our scenario simulations focus on deviations from the base simulation described in Section 2 that are induced by a specific exogenous change. We begin with three scenarios regarding a one-period change in 1969 which illustrate some features of the model of SAT agriculture more clearly than do the scenario with sustained changes. We then consider a hypothesized productivity increase over several years in sorghum production, and subsequently a series of other sustained changes. The first three scenarios are summarized in Table 3; the other in Table 4.

Scenario 1. One Standard Deviation Shortfall in Rainfall in 1969. The variation in rainfall in the Indian SAT is substantial and causes considerable problems for agricultural production. The model incorporates a rainfall variable (see Table 1), although the discussion relating to the errors in the base simulation in Section 2 suggests that the rainfall variable represents only a part of important environmental conditions. The timing of a given amount of rainfall, for example, may be critical -- and there are enormous variations from year to year in the intrayear patterns of Indian SAT rainfall. Since the rainfall index in the model does not capture such details as timing, it understates the overall importance of rainfall. Nevertheless, it is of interest to explore what would be the impact of an additional shortfall in rainfall (deducted from the actual level) within the structure of our Phase I model.

Columns (4) and (5) in Table 3 summarize the percentage deviations from the base simulations in 1969 and 1970 induced by the rainfall shortfall in 1969. (There are no effects as large as 1% that are induced in subsequent years).

In 1969 overall production falls, but there is a compositional shift with increases induced in sorghum and other coarse cereals. The fall in production lowers overall SAT consumer expenditures and shifts downward the demand curves for all demand categories. Because of the increased

20 We also have conducted other simulations which we do not discuss here. For example, we have explored what would happen were fertilizer prices to be shifted upward by 10%. However, because of some peculiar coefficient estimates associated with fertilizer in the BBQ supply system (see Table 1), this simulation has implications which do not seem very plausible. Therefore, we do not discuss the results here, but suggest that further investigation of the role of fertilizer in supply be undertaken in subsequent phases of the project. Since the fertilizer prices are held constant in other simulations, there is no feedback through them of any effects associated with the peculiar coefficient estimates related to fertilizer.

21 For such reasons the magnitude of the simulated impact of the rainfall drop probably is small but the directions of induced changes and feedbacks still may be of interest.
supplies of sorghum and other coarse cereals, nevertheless, for these two commodities the prices fall and added consumption is induced with a movement down the (downward-shifted) demand curves. In contrast for pulses and oilseeds - edible oils, the reduced supply causes price increases and a movement up the (downward-shifted) demand curves, so quantities consumed fall. Also, for superior cereals and the other item demand category with prices fixed in both cases in the rest of India, quantities demanded in the Indian SAT fall, so net imports from the rest of India fall. Because of the decline in production of fertilizer-using crops, finally, fertilizer demand -- and therefore fertilizer imports into Indian SAT -- decline.

In 1970, most of the effects are less than 1% in absolute value. But there are a few lagged responses of this or greater magnitude. In particular due to the impact on expected pulses prices for 1970 of the higher induced pulses price in 1969, pulses production increases in 1970 by about half of the amount of the fall from the base simulation path in 1969. Associated with the crop expansion is an increased demand for fertilizer and, in order to clear the short-run pulses market in Indian SAT, a fall in the 1970 pulses price.

Therefore, this scenario provides illustrations of several important points: (i) Exogenous changes may induce significant compositional changes in both production and demand and thus have effects of differing sign on prices and on net imports into SAT. (ii) Because of these dynamic responses to expected prices, the response to a one-period exogenous change may persist over several years. (iii) Further, that response may reflect some cycling (as with pulses and fertilizer) before the return to the base simulation path. (iv) At least in this case, however, the model is fairly stable so the simulation values basically return to the base paths within a year or two.

Scenario 2: 10% Increase in Noncrop SAT Income in 1969: Part of the expenditures on SAT agricultural production within SAT originates in noncrop activities, such as from animal husbandry and in that part of manufacturing which is not dependent on inputs from SAT agricultural production. This scenario explores what happens if there is an increase in such income (i.e., in \( Y_0 \) in relation 11). Columns (6) - (8) in Table 3 give the induced percentage changes in 1969-1971 from the base simulation paths of a 10% increase in noncrop income in 1969 only.

In 1969, of course, there are no supply responses. As a result, all of the endogenous prices increase a fair amount, with the 11.4% change for pulses being the largest. These price increases are necessary to move up the demand curves given the fixed quantities supplied and the upward-shifted demand curves (due to the increased income). For superior cereals and the other items demand category in which prices are fixed exogenously in the rest of India, the upward shift in the demand curves cause substantial increases in net imports (about 9% of total base simulation demands) to satisfy the increased demands.
Table 3. Summary Measures of Percentage Errors in Base Simulations and Percentage Deviations from Base Simulations Induced in Three Scenarios for Changes in 1969 Only

<table>
<thead>
<tr>
<th>Endogenous Variables</th>
<th>Base Simulations</th>
<th>Percentage Error</th>
<th>Percentage Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAPE</td>
<td>RMPE</td>
<td>SAT Income in 1969</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Output Supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>superior cereals</td>
<td>5.5</td>
<td>7.5</td>
<td>10.7</td>
</tr>
<tr>
<td>sorghum</td>
<td>9.7</td>
<td>8.4</td>
<td>9.9</td>
</tr>
<tr>
<td>other coarse cereals</td>
<td>10.3</td>
<td>13.4</td>
<td>17.0</td>
</tr>
<tr>
<td>pulses</td>
<td>8.6</td>
<td>17.3</td>
<td>23.7</td>
</tr>
<tr>
<td>oilseeds</td>
<td>9.8</td>
<td>15.8</td>
<td>21.3</td>
</tr>
<tr>
<td>other crops</td>
<td>8.3</td>
<td>7.9</td>
<td>8.5</td>
</tr>
<tr>
<td>Input Demand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fertilizer</td>
<td>14.4</td>
<td>24.8</td>
<td>29.9</td>
</tr>
<tr>
<td>labor</td>
<td>1.4</td>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sorghum</td>
<td>5.0</td>
<td>21.4</td>
<td>30.2</td>
</tr>
<tr>
<td>other coarse cereals</td>
<td>14.1</td>
<td>35.2</td>
<td>46.4</td>
</tr>
<tr>
<td>pulses</td>
<td>15.0</td>
<td>10.9</td>
<td>16.8</td>
</tr>
<tr>
<td>oilseeds-edible oils</td>
<td>16.5</td>
<td>20.3</td>
<td>23.4</td>
</tr>
<tr>
<td>Demand Quantities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>superior cereals</td>
<td>16.0</td>
<td>17.9</td>
<td>20.6</td>
</tr>
<tr>
<td>other items</td>
<td>4.4</td>
<td>6.1</td>
<td>9.0</td>
</tr>
<tr>
<td>Expenditure</td>
<td>1.5</td>
<td>2.1</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Note: Base simulation, MAPE, and RMPE are defined and discussed in Section 2. Scenarios are defined and discussed in Section 3; this table gives percentage deviations from the base simulation for these scenarios.
The impact of this process on SAT expenditures is quite interesting. The total effect is an 8.1% increase in 1969. Of course, part of this is just due to the added exogenous income. But the total increase in expenditure is substantially larger than the exogenous increment because of the feedback of the increased prices. That is, the income of SAT producers of sorghum, other coarse cereals, oilseeds, and particularly of pulses are increased in the process because their fixed supplies can be sold at higher prices. Therefore the shifts in demands noted above are due not only to the exogenous increase in income, but also reflect endogenous income increases for SAT crop producers.

In 1970, the changed expected prices for SAT crops (due to higher prices for four of the six categories in 1969) cause an expansion of SAT agricultural production. However, because of the differential responses within a system context, the expansion is not at all uniform. For example, for both sorghum and other coarse cereals, price increases of 4.6% above the base simulation are induced for 1969, the own-price elasticities are about 0.4 (see Table 1), and the price expectation generating mechanisms is identical (relation 3). But in 1970 sorghum production is induced to expand above the base simulation level, while other coarse cereals actually contract because of the expansion of pulses at the expense of other coarse cereals (see Table 1). It is also noteworthy that the crop expansion induces an increase of 5.6% in fertilizer demand in 1970, due entirely (though indirectly) to a 1969 increase in noncrop SAT income.

Another interesting feature of the 1970 results is the limited effect on expenditure. In this year, the induced changes in production are just about offset by induced changes in prices. As a result, there are not substantial shifts in demand curves due to income changes, nor any large induced changes in net imports of superior cereals and of the other items demand category.

In subsequent years, most of the effects are dampened considerably. Nevertheless there are some effects larger than 1% in absolute value with some cycling which persist into 1971 and beyond, particularly regarding quantities and prices of pulses and quantities of fertilizers.

Scenario 3. An Increase in the Inventory Holdings of Sorghum Equal to 10% of Production in 1969: In our basic model we assume that all inventory changes are proportional to supply or demand as is indicated in relations (7) and (8). This strong assumption is necessary because of the absence of data on inventories. However, as we discuss in Section 1, we can simulate what would happen if actual inventory behavior deviated from this assumed "normal behavior," for example due to government purchases, acquisition of inventories by speculators, or whatever. In this scenario we investigate the impact of such a possibility in the case of sorghum in 1969. Columns 9 and 10 in Table 3 summarize the results.

In 1969 the most important impact is an increase in the sorghum price of 4.9%. This increase occurs in order to accommodate the added inventory absorption by reducing other demand, given the short-run fixed supply of sorghum. The same higher price, however, in the next year induces an expansion of sorghum production of 1.6%, which causes a price decline of 2.3% in that year. All in all, sorghum producers benefit from the added
inventory accumulation. Of course the benefits may be reversed if (when?) these stocks are sold subsequently.

Scenario 4. Increase in Sorghum Productivity. One of the primary interests of ICRISAT is to increase productivity of the five mandate crops. But such increases may have effects throughout SAT agriculture through market channels. Some analysts claim that sorghum productivity increases will not increase output much because induced sorghum price declines will lead to a large cutback in sorghum. Therefore it is of considerable interest to explore the impact on the whole system of changes in the productivity of a given crop.

In our model, since crop output but not yield or area, is a decision variable to the farmer, any productivity change is modelled to have three components; supply shift, reallocation of resources due to change in the profitability of the crop concerned and market effects. Of the above three effects, the first two come from the supply side and the third from the demand side of the model. In this scenario we assume that productivity in sorghum production increases, with a maximum increase in the growth rate of 5% in the fifth year (1973), but with smaller increases in earlier and subsequent years. Columns 1-3 in Table 4 give the induced deviations from the base simulation paths for 1971, 1974, and 1978 under this scenario.

The magnitudes of the impact of the assumed productivity increase in sorghum change over the decade because of the assumed pattern of initially increasing and subsequently decreasing productivity growth. But the general implications are the same over time.

First of all, there is the anticipated negative impact on the sorghum price in order to absorb within the Indian SAT region the increased sorghum production. By the tenth year of the simulation the decline in price is -12.7% (for an increase in production of 33.1%). This discourages somewhat sorghum production so output does not increase as much as it should. Second, sorghum output does, nevertheless, increase more than sorghum productivity: in the tenth year sorghum output is 33.1% above the base simulation path even though productivity is 25% above the base path. The larger increase in output than in productivity despite the price decline reflects that the second reallocation effect (positive) more than compensates the third market effect (negative). Thus, contrary to the apprehensions noted above, sorghum productivity increase did get translated into output increase.

In the absence of all demand considerations, a 25% increase in sorghum productivity could have increased its output by 35% because sorghum supply elasticity is 0.4 (see Table 1). On the average,

22 The exact pattern of assumed annual increases is: 0.5%, 1.5%, 3.5%, 4.5%, 5.0%, 4.5%, 3.5%, 1.5% and 0.5% during 1969-1977, respectively. After the ninth year this leads to a (cumulative) productivity path 25% above that of the base simulation. This pattern is chosen to reflect a typical stylized adoption process.
Table 4. Scenarios of impact of sustained exogenous changes on Indian SAT crop markets

<table>
<thead>
<tr>
<th>Endogenous Variables</th>
<th>4. Productivity</th>
<th>5.10% Increase in sorghum production</th>
<th>6.10% Increase in road density (market access)</th>
<th>7.10% Increase in Irrigation</th>
<th>Noncrop SAT Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>superior cereals</td>
<td>0.1 0.0 -0.0</td>
<td>1.5 1.0 2.9 3.1 -0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sorghum</td>
<td>7.6 26.3 33.1</td>
<td>0.4 0.2 -0.3 -0.0 1.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>other coarse cereals</td>
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Note: These scenarios are defined and discussed in Section 3. This table gives the induced percentage deviations from the base simulation.
sorghum producers have greater gross revenues since the increase in production is much larger than the decline in price. But the impact of any productivity improvement is not likely to hit all farmers equally because of differences in land quality, water control, management capabilities, etc. Those sorghum farmers who experience little or no sorghum productivity increase, in fact, will be worse off because of the lowered sorghum price.

Second, the larger sorghum production and lower sorghum price means that Indian SAT consumers of sorghum are undoubtedly better off due to this productivity change. Since sorghum constitutes a higher share of the budget of poorer individuals (see Murty), these benefits accrue relatively more to the poorer members of society.

Third, even though the systemic effects are relatively weak for sorghum (in the sense that the cross price elasticities in tables 1 and 2 are small), there are some impacts on other commodities at least of the magnitude of 2% by the end of the decade. Due to the lower sorghum price, for example oilseeds substitute somewhat for sorghum in production and sorghum substitutes somewhat for superior cereals and other coarse cereals in consumption - which lowers net imports of the former and the price of the latter. None of these effects is all that large, however. Judging by the cross-elasticity estimates in Tables 1 and 2, the systemic effects would be relatively greater, for example, for productivity changes in superior cereals.

Scenario 5: 10% Sustained Upward Shift in Road Density (or Market Access)

Road density is hypothesized to affect production decisions through changing market access in relation (2). The estimates in Table 1 suggest differential effects across crops. Columns 4 and 5 in Table 4 give the simulated percentage deviations from the base simulation paths in 1969 and 1974 for a sustained 10% upward shift in road density.

In 1969 the direct impact is to change the composition of production and to increase fertilizer usage. The largest percentage increase in production is 6.7% for the other crop category, which is plausible since these are relatively commercialized crops. There also are smaller percentage increases in cereals. The largest percentage drop is -7.2% for oilseeds. This may be somewhat surprising since oilseeds also are fairly commercialized, at least in comparison with coarse grains and pulses (the latter of which declines slightly). But the environmental conditions and technological substitution possibilities embodied in the estimates of Table 1 result in the expansion of the other crop category at the expense primarily of the fairly commercialized oilseeds and secondarily of less-commercialized pulses, but not at the expense of relatively uncommercialized coarse grains. Of course the induced compositional changes result in price increases for pulses and oilseeds - edible oils in order to reduce the quantity-demanded to the lower quantity-supplied along basically stable demand curves.
In subsequent years, the effects are generally the same. However, an interesting feature is that for the most part the percentage deviations from the base simulation paths are somewhat less than those in the first year. This is the case because the endogenous price changes due to given supply changes induce somewhat offsetting subsequent supply responses.

Scenario 6: 10% Sustained Increase in Area Under Irrigation. Judging by the estimates in Table 1, expanded irrigation tends to induce most production of superior cereals and oilseeds and somewhat less so production of the other crop category and other coarse cereals. Columns 6 and 7 in Table 4 summarize the impact in 1969 and 1974 of a sustained increase in irrigation.

In 1969 the induced percentage output expansions are roughly in the order indicated by the output elasticities with respect to irrigation in Table 1, though not exactly. To illustrate, the induced expansion of 2.9% for superior cereals is not the largest; that of 3.4% for oilseeds is greater because of differential patterns of cross substitutions. However, in later years the percentage deviation is greater for superior cereals than for oilseeds (see column 7 for 1974). This occurs because the oilseed price reduction discourages somewhat subsequent oilseed supplies, but superior cereals prices are unaffected since Indian SAT production is such a small proportion of total Indian production.

Scenario 7: Sustained 10% Increases in Noncrop SAT Income. This scenario is identical to scenario 2 except the income increase is sustained instead of being only for 1969. The first year results, of course, are those presented in column 4 of Table 3 and discussed above in scenario 2. Column 8 of Table 4 gives the results in 1974, by which time the discrepancies from the base simulation paths have stabilized substantially.

These percentage deviations for 1974 generally are about the same or smaller for quantities than in 1970 for scenario 2 and smaller for prices than in 1969 for scenario 2. The steady state in this scenario, thus, strikes a balance between the first-year price effects and the second-year quantity responses in the one-year change of scenario 2. The resulting steady impact on expenditure is about 7.5% above the base path simulation, suggesting that the combined steady-state price and supply increases magnify the effect of the sustained exogenous noncrop SAT income increase much as do the price effects alone in the first year of scenario 2.

Section 3. Conclusion and Future Work Plan

Data limitations have forced us to incorporate some simplifications in the specification on the Phase I model, as noted above. Nevertheless, our simulations help fill some important voids in knowledge regarding
agricultural markets in SAT India within a systems context with important contemporaneous and lagged dynamic feedbacks in localized markets such as those for coarse grains and pulses. The most important general implication of our investigation to date is that the feedbacks through prices for the crops in localized markets change significantly the impacts from those that might be anticipated from examining the supply system alone. For Example, the impact of rainfall fluctuations or irrigation increases on the composition of output differs from that suggested by the supply-side estimates alone due to induced changes in prices of the coarse grains, pulses, and, to a lesser extent, oilseeds.

The most important illustrations regard local infrastructure and productivity improvements for the crops traded in the locally-isolated markets. In both cases the initial improvements induce expanded production that drives down prices of these products. The lower prices, in turn, induce lower subsequent supplies and real income of the producers of these crops than would occur if prices were unaffected. The aggregate position of producers, therefore, is bettered less by these improvements than might appear to be the case from the consideration of productivity effects alone (though output still increases because the productivity rise dominates the supply response to the lower price). The position of the producers who directly benefit less from the improvements due to the location of infrastructure changes or the differential applicability of technological changes, moreover, may be worsened significantly by the lowered prices. For such reasons the expected gains from such improvements may be considerably less and distributed differently than a more partial focus on production and supply alone would suggest.

We think this and other insights illustrate the value of continued work on scenario analysis on SAT agricultural markets. Therefore we propose an ongoing work program, with both short-run and longer-run components.

The short-run work program involves the following components:

1. Exploration of alternative available supply systems: BBQ present alternative supply system estimates, which, in recent conversation, they claim are preferable to the system A used in the Phase I model. We propose to explore the impact of using such estimates in the systems simulations. Examination of their alternative estimates suggest that using them may improve some dimensions of the model, though some problems will remain (e.g., some of the effects of fertilizer prices).

2. Incorporation of MR demand estimates by income strata and exploration of differential impacts on consumer and real income, Welfare and nutrition: Mellor has emphasized the impact of food prices on real incomes of low-income consumers in developing countries. Pinstrup-Anderson (and collaborators) and Ryan have explored the impact on consumer welfare
and nutrition. We propose to expand these explorations by incorporating the MR demand system estimated by income strata. By doing so, we can explore the important results of these earlier studies within a framework with systemic interactions, differential responses by income class, and feedbacks between supply and demand for output and output production and income. The same expanded demand system will permit systemic extensions of the Mellor-Pinstrup-Anderson-Ryan type investigations to other changes like infrastructure and productivity improvements.

The long-run work program is more tentative, but a major component will be the further exploration of the supply system and the elaboration of the labor market. The BBQ supply system currently used, as well as their alternatives, have some peculiar signs related to fertilizer and surprisingly low elasticities of demand for labor. Another shortcoming of the present supply systems is their limited attention to dynamics which, as Nerlove and others have emphasized, may be critical. The longer-run work program would involve re-estimation of the supply system with particular emphasis on the role of fertilizer and labor, and on dynamics. Discussion with ICRISAT staff also may indicate further dimensions of the supply system which merit more detailed exploration. Of course this re-estimation will benefit from the availability of considerably more data than BBQ had at their disposal. In addition to the re-estimation of a modified supply system, development of the labor market in the model will require elaboration of labor supply determinants.

Other long-run improvements in the model depend critically on data available. If data can be located, for example, it would be desirable to estimate relations for the determinants of inventory holdings by various entities and of net import flows.

In our judgement the Phase I model results are sufficiently rich and interesting and the work program sufficiently promising that the work program should be undertaken.
References


