Economics Program
Progress Report 39

Scenario Analysis of Impacts of Changes in Technology, Fertilizer Prices, Highways, Labor Markets, Consumption Expenditure, Rainfall and Price Policy for Semi-Arid Tropical Crop Markets

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June 1982

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SCENARIO ANALYSIS OF IMPACTS OF CHANGES IN TECHNOLOGY, FERTILIZER PRICES, HIGHWAYS, LABOR MARKETS, CONSUMPTION EXPENDITURE, RAINFALL AND PRICE POLICY FOR SEMI-ARID TROPICAL CROP MARKETS

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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 demand patterns. Furthermore the productivity change for the original crop may induce shifts in demands for inputs like hired labor and fertilizers, with possible repercussions on 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.

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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 I 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 parametrization. Section 2 gives some examples of the nature of interactions among crops and of dynamic responses within this sytem. Section 3 considers simulations of system-wide responses to a variety of scenarios of changes in productivity, fertiliser prices, highway infrastructure, labor market conditions, total consumption expenditure, rainfall, and price policy.

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

Modeling by definition requires abstraction from the complexity of reality in order to focus on the essential elements of the phenomenon under investigation. In empirical application often further abstractions of theoretical models are required due to unavailability of certain data. In our modeling 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 93 districts in the four states of Tamil Nadu, Karnataka, Andhra Pradesh and Madhya Pradesh for the years 1955/56 through 1973/74 by ICRISAT. These data cover 22 principal crops, including all 5 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 barnycod millets), and other minor millets.
Six pulses	:	chickpea (bengal gram), pigeonpea (tur or red gram), green gram (mung), black gram (urad), horsegram (kulthi), and other pulses.
Four oilseeds	:	groundnuts, sesamum, castorbean, linseed.
Four other crops	:	sugarcane, cotton, tobacco, chillies.

For some purposes the districts are aggregated into 17 agroclimatic subregions on the basis of average annual 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 these 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 "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 (but not both) are produced in each of their agroclimatic subregions.

2. Sorghum is grown in virtually all subregions and therefore 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_2O_5, and K_2O. 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 (eg. 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/km^2 which BBQ suggest is their best measure of market access.

4. Regulated market density in number/1000 km^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 models for one observation can be represented in vector notation as:

(1) $S = f(P^E, X, U)$

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^E is a six element vector of expected prices at the time of production decisions with one element corresponding to each element 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 for the i^{th} crop supply (or factor demand), which we approximate below, is in growth rate form:

$$(2)\quad \dot{S}_i = \sum_{j=1}^{6} E_{S_i P_j^E} \dot{P}_j^E + \sum_{j=1}^{7} E_{S_i X_j} \dot{X}_j + E_{S_i U_i} \dot{U}_i$$

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

E_{YZ} is the elasticity of Y with respect to Z ($= (\partial Y/Y)/(\partial Z/Z)$); 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 ($\dot{P}_j^E$), 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 demands, 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 demand 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 since 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 (ie. the implied substitution between crop i and crop j is the same whether viewed from the point of view of crop ir 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 (eg. 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 real world lags are different). Though these costs are not negligible, they certainly are outweighed from our view point by the advantages of the systemic approach (particularly since not we, but BBQ, have borne the 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 assumption about expected price formulation is required. After experiments with various lag structures, BBQ adopted the following uniform specification for all expected crop prices:

$$(3)\ P_i^E = 0.71\ P_{i,-1} + 0.29\ P_{i,-2}$$

where P_i is the actual price of the i^{th} crops (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 i^{th} crop (input) in the t^{th} period in a particular district can be decomposed into three independent normally distributed components: one which is common across the districts in the same agroclimatic subregion for that crop, a second which is common over time within that district for that crop, and a third which is independent of the disturbances for other time periods, districts, 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 bases of pooled time series (17 years, after 2 are lost due to the lag structure in relation 3) and cross-section (X districts, after some are deleted because they do not seem to fall into the CAT classification) data. The combination of cross-section and time series data permit added precision in the estimates.

Table 1 summarizes the implied elasticities at the points of sample means for the normalized quadratic system.[1] 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.[2] The elasticities imply a number of significant cross-crop effects in that 14 of the cross price elasticities are based on significantly nonzero coefficients estimates at least at the 10% level. They also imply some

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. 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.

Table 1. Crop output supply and fertilizer input demand elasticities for SAT India

	Output supply elasticities for:						Fertilizer input demand elasticities
	Superior cereals	Sorghum	Other coarse cereals	Pulses	Oilseeds	Other crops	
Expected prices of:							
Superior cereals	.36[a]	.01	-.27	.06	-.31[b]	-.12	-.45
Sorghum	.00	.15	.02	.45[a]	-.04	-.04	-.14
Other coarse cereals	-.09	.01	-.13	-.22[c]	.18[b]	.15[a]	-.49[b]
Pulses	.01	.25[a]	-.16[c]	.43[b]	.05	-.03	.79[a]
Oilseeds	-.13[b]	-.04	.24[b]	.10	-.01	.06	.24
Other crops	-.07	-.06	.25[a]	-.08	.08	.06	.18
Other variables							
Fertilizer price	.05	.03	.15[b]	-.34[a]	-.06	-.03	-.28
Wage rate	-.13	-.36[a]	-.10	-.39[a]	.10	-.04	.14
Rainfall	.32[a]	-.20[a]	-.09	.26[a]	.07	.16	.22
High yielding varieties	.07[a]	-.04[a]	-.06[a]	.09	.04	.17[b]	.24[a]
Road density	.18[a]	.04	.08	-.19[b]	-.68[a]	.75[a]	1.04[a]
Regulated market density	.07[b]	.05	.13[a]	-.02	-.35[a]	.08	.37[a]
Irrigation	.32[a]	-.03	.17	.10	.30[b]	.22	.31

Source: Normalized quadratic profit function estimates, evaluated at point of sample means, for expected prices from Table 5 and for other variables from Table 6 in BBQ.

a. Underlying parameter significantly nonzero at 1% level

b. Underlying parameter significantly nonzero at 5% level

c. Underlying parameter significantly nonzero at 10% level.

other interesting significant patterns: 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 crop category and an increase in fertilizer demand, presumably all due to the improved market access; increased regulated market density causes a shift from oilseeds to superior cereals and the other coarse grains category and an expansion of fertilizer demand; and increased irrigation causes expansion of superior cereals and of oilseeds with no significant impact on other crops nor on fertilizer demand.

But some of the elasticities based on insignificant coefficient estimates have a priori peculiar signs -- in particular, the own price elasticities for the other coarse cereals and for oilseeds, both of which are negative.[3] Since such signs may cause distortions in the simulations and since the underlying coefficient estimates are not significantly different from zero at the 10% level, in our Phase I model we set equal to zero all elasticities for which the underlying coefficient estimates are not significantly different from zero at the 10% level.

However, in three cases (ie. sorghum, groundnuts, fertilizer) the insignificant own price elasticities seem to reflect the aggregation of agronomic subregions in which rice is the dominant superior cereal alternative together with ones in which wheat is the dominant superior cereal alternative. With greater disaggregation the parameters underlying these own price elasticities are significantly nonzero at least at the 5% level. Therefore as one variant of the Phase I model we consider simulations in which the arithmetic average of significant own price elasticities from the estimates based on geographical disaggregation between wheat dominant and rice dominant SAT are used for these three commodities: sorghum (.62), oilseeds (.23), and fertilizer (-.45).

3. As BBQ note, perhaps for this reason their system estimates reject the symmetry constraint derived from profit maximization under the assumption that there are no specification errors (broadly construed). But as they also note, whatever the reason for the rejection of the symmetry constraint, the estimated systems of output supply and input demand are useful so long as the underlying behavioral and technological relations are sufficiently stable.

<u>Demand</u>: 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 MR.[4,5]

The data base for the 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 the supply estimates above.[6]

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

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 non-food goods. Therefore, we do <u>not</u> 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

4. 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.
5. Work is still underway by MR. Future extensions may include estimates based solely on the SAT area.
6. Actually MR have 15 commodities but we aggregate them to make them as comparable as possible with the first five categories of HBQ and include all of the other items in MR's study in demand category six.

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 MR demand system chickpeas are included in category four instead of in category three as in the BBQ supply system.

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

(4) $D = g(P^D, Y, V)$

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:

$$(5)\ \dot{D}_i = \sum_{j=1}^{6} E_{D_i P_j^D} \dot{P}_j^D + E_{D_i Y} \dot{Y} + E_{D_i V_i} \dot{V}_i$$

Where the conventions defined below 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 ($\dot{P}_j^D$), of expenditure ($\dot{Y}$), and of the disturbance ($\dot{V}_i$), 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 power.[7] To estimate the parameters of relation (4) which underlie the elasticities in relation (5), some specific functional forms must be used.

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.

MR utilize the Nasse 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 likehood 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. But those for sorghum (-.39) and to lesser extent for edible oils (-.62) indicate substantially less direct own-price response than for the other four categories (-.88 to -.98), which are almost unitary.

Second, there are some fairly large 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 5% and 2% respectively in quantities demanded of other coarse cereals and of sorghum, and decreases of -3.8% for edible oils and of -2% of both pulses and all other commodities. The only other cross-price elasticity even half as large in absolute value as the smallest of these

8. To satisfy the convexity conditions, MR impose the restriction that non-food groups are additively separable, thus reducing this part of the model to a linear expenditure system.
9. This expenditure group is 8-13, 1961-62 rupees per household per month (or about X to Y 1981 rupees per household 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

	Demand elasticities of commodities					
	Superior cereals	Sorghum	Other cereals	Pulses	Edible oils	Other commo- dities
With respect to price of:						
Superior cereals	-.95	.20	.53	-.20	-.38	-.19
Sorghum	-.04	-.39	-.02	-.03	-.05	-.03
Other cereals	.07	.01	-.98	-.07	-.12	-.06
Pulses :	-.01	-.00	-.01	-.89	.04	-.00
Edible oil	-.03	-.01	-.01	.03	-.62	-.00
Other commodities	-.09	-.02	-.05	.01	.01	-.88
With respect to total expenditures:	1.06	.20	.54	1.14	1.12	1.16

Source: Nasse expenditure system estimates for second lowest expenditure class from unpublished data in work summarized in MR.

for superior cereals is the response of -1.2% in edible oil demand to a 10% increase in the price of other cereals.

Third, the expenditure elasticities vary considerably, with those for sorghum (.20) and for other coarse cereals (.54) being relatively irresponsive. In contrast, the expenditure elasticities for the other four categories all are slightly above unity (1.06 to 1.16). Thus, as income and expenditure increase, ceteris paribus, there is the well-known shift in expenditure shares away from sorghum and other coarse cereals to the other food and nonfood categories.

<u>The Production Equals Absorption Identity</u>: For the i^{th} commodity in SAT agriculture the total supply is SAT production (S_i) plus net imports into SAT (M_i).[11] 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 (ΔI_i^P), consumers (ΔI_i^C), market wholesalers and retailers (ΔI_i^M) and by public authorities (ΔI_i^G). In addition, there is significant wastage (W_i), including spoilage and loss to insects and other animals. Total production equals total absorption.

$$(6)\ S_i + M_i = D_i + L_i + R_i + \Delta I_i^P + \Delta I_i^C + \Delta I_i^M + \Delta I_i^G + W_i$$

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 the first five commodity groups:

$$(7)\ aS_i = L_i + R_i + \Delta I_i^P + W_i - M_i$$

Likewise, for these commodity groups, we assume that the sum of other (ie. non-producer) inventory changes is proportional to demand:

$$(8)\ bD_i = \Delta I_i^C + \Delta I_i^M + \Delta I_i^G$$

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11. Which, of course, are negative if exports exceed imports.

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

$$(6A)\ (1-a)S_i = (1+b)D_i$$

so that:

$$(6B)\ \dot{S}_i = \dot{D}_i$$

And, of course, relation (6B) can be utilized with relation (2) substituted in the left-hand side and with relation (5) substituted in the right-hand 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 these other items. 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 2% 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:

$$(6C)\ \dot{S}_i - .02 = \dot{D}_i$$

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:

$$(6D)\ \dot{S}_i + .01 = \dot{D}_i$$

Second, the assumption that net imports are proportional to supplies probably is a palatable approximation for the first five commodities. 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, reinforced at times by government food zone policies and other regulations. 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 discussed for the other commodities in the next paragraph.

For the other three commodity supplies or demands in the model -- the other crop supply category, fertilizer demand, and the other commodity demand category -- we do not include both production and absorption within the model. We do not do so because in these cases, integration into the larger Indian market and/or government policies (particularly for fertilizer) means that net imports are relatively large and variable in comparison to SAT production. In these cases we assume that prices are set in the larger Indian 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.

Third, 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 system estimates and the MR demand system 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.

Supply and Demand Price Relations: We have discussed how prices are determined outside of the Phase I model for the other crops supply category, for fertilizers, and for the other commodity demand category. But for the other five commodities on the supply side there are expected prices (P_i^E) based on actual supply prices (P_i) as indicated in relation (3) and prices which consumers pay on the demand side (P_i^D). 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:

$$(9)\ P_i^D = m_i P_i$$

For our Phase I model we assume that these factors of proportionality are constant for each commodity (not across commodities)[12] so that:

$$(9A)\ \dot{P}_i^D = \dot{P}_i$$

With the added assumption that the prices of the first five commodity groups adjust within each year to clear approximately the individual markets, the Phase I model solves for these 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 relations (2), determine the rates of growth of supplies of each of the commodities through relations (2). This fixes for that year the left-hand side of relations (6B). By substituting relations (9A) into the rate of growth in demand in relations (5) and substituting the resulting relations into the right-hand side of relations (9A), a system of expressions is obtained in which the rates of changes of the prices are the only unknowns. This system can be solved for these prices. In this process current quantities supplied are given by responses to expected prices based on past prices, and current demands and current prices adjust so that the rates of growth in supplies equal those for demand.

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

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.

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 ($\Sigma S_i P_i$) minus expenditures on fertilizer ($S_7 P_7$) plus other net expenditures (Y_o) which are independent of price and quantity movements for the commodities of concern:[13]

$$(10)\ Y = c' \left(\sum_{i=1}^{6} S_i P_i - S_7 P_7 \right) + Y_o$$

The components of Y_o 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 right-side expression in relation (10) is an overstatement of expenditure from SAT agricultural production to the extent that other non-fertilizer inputs and savings are not deducted from the gross value of production, which implies a value of c' below one, ceteris paribus. In the Phase I model we assume that the net impact of these considerations can be represented by the following approximation at the margin:

$$(10A)\ \dot{Y} = C\ \dot{Z} + \dot{Y}_o$$

where $Z = \sum_{i=1}^{6} P_i S_i - P_7 S_7$

We use a base value of $c = 0.6$, but explore the sensitivity of our results to changes in this value.[14]

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 marked prices underlay a debate of some years ago regarding indirect measures of the price elasticity of the marketed surplus between Krishna 1965 and Behrman 1966.
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.

Section 2. Simulation Process and Examples of Interactions and Dynamics

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 interactions and dynamics.

Model Summary: The model of the previous section can be briefly summarized 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 four prices (ie. for fertilizers, labor, other commodities supplied, and other commodities demanded), the other five variables that enter into the supply system (ie. rain, high yielding varieties, road density, regulated market density, and irrigation), the exogenous part of expenditure (Y_o), 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 (10A) is set equal to 0.6.

Recursive Block 1: The current expected prices for the 6 output commodities supplied (P_i^E) are determined from lagged farm prices ($P_{i,-1}$, $P_{i,-2}$) as indicated in relations (3).

Recursive Block 2: The current quantities supplied of the 6 commodities in S and of fertilizer input demanded are determined by the current expected prices (P_i^E), by the previous year's quantities and relations (2).

Simultaneous Block: Given the current quantities supplied, relations (5), (6B), and (10A) determine simultaneously the current prices for each of the six agricultural commodities (P_i) 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 in linearly. Therefore, even the most complicated part, the Simultaneous Block, could be solved for prices explicitly by inverting a 6 x 6 parameter matrix. However, instead we use an iterative Gauss-Seidel procedure since future model phases will have nonlinearities, the algorithm input is straight forward 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] For our scenario simulations we use as a reference point our base simulations with the model structure as indicated above, and then indicate how the hypothesized change in each scenario changes the endogenous variables from their base value time paths.

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 (eg. 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 1981, and studying the impact of human capital investments and demographic changes on income distribution in a developing country in Behrman, Wolfe, and Blau 1981 and Wolfe, Behrman and Blau 1982).

Section 3. Simulations for Scenario Analysis

1. **Rain Effects**: Focus on differential impact on crops, dynamic impact over time, and impact of sustained versus one year drought.

    1A. One standard deviation shortfall in rainfall in year 1
    1B. One standard deviation shortfall in rainfall in years 1-3

2. **Productivity Increases**: Focus on interaction among crops, dynamic paths, and offsetting responses due to damped prices.

    2A. S-shaped improvement in sorghum productivity of about 10% in 5 years (ie. for sorghum in relation (1) add 1% in year 1, 3% in year 2, 7% in year 3, 9% in year 4, and 10% thereafter).
    2B. 10% sustained increase in use of high yielding varieties (given their historical composition among crops).

3. **Infrastructure Development**: Focus on returns, differential impact among crops, and dynamic effects of 10% improvements in:

    3A. Road density
    3B. Regulated Market Density
    3C. Irrigation

4. **Market and Related Policy Changes**: Focus on differential impact among crops, indirect effects, and dynamic effects of:

    4A. 10% sustained increase in fertilizer price
    4B. 10% sustained increase in agricultural wages
    4C. One period diversion of 2% of supply to private speculative stocks for superior cereals
    4D. One period diversion of 2% of supply to private specultiave stocks for all cereals
    4E. Sustained price floor for superior crops (with endogenous additive term in relation 6B to indicate how much additional government stock acquisitions would be needed).
    4F. Sustained price floor for all cereals.
    4G. Shortage of fertilizer at fixed price (make "shadow" price of fertilizer endogenous, given fixed quantity, and calculate rents to those who receive fertilizer).

5. **Sensitivity Analysis**: Explore how results of some particular simulations (eg. 2A, 3C, 4A) depend on alternative assumptions regarding:

    5A. Own price supply elasticities for sorghum, oilseeds, and fertilizer.
    5B. Role of SAT crop income in determination of SAT total expenditure (ie. value of c in relation 10A).
    5C. Whether or not superior grains and oilseeds - edible oil SAT markets are well integrated into all-India markets.

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JRB:KNM:sh
7 July 1982