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Potential and Challenge

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IMPACTS OF HYPOTHETICAL CHANGES IN PRODUCTIVITY AND RAINFALL ON AGGREGATE CROP PRODUCTION, CONSUMPTION, PRICES, AND INCOME IN DIFFERENT CROPPING ZONES OF SAT INDIA*

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Abstract

Planners and irrigation experts in India now feel that increasing agricultural production either through area expansion or irrigation development has reached a saturation point, and that the development of dryland agriculture through appropriate technology, based both on crops and on farming systems, is the only alternative. Since a majority of farmers in dryland areas grow crops for consumption, there is need to link both supply and demand for these crops. Such an approach would help in simulating impacts of certain exogenous changes in rainfall distribution, productivity growth and other behavioural parameters. These impacts would have both allocative and dynamic feedbacks through income, prices, etc.

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This paper briefly discusses the simulation methodology and analyses the utility of data that quantify demand/supply parameters, and the base simulations which serve as reference to all other scenario simulations. Major inferences of the study are: 1. farmers in SAT India respond even for rainfed crops; 2. there are significant cross-crop responses in dryland farming, particularly between rainfed crops and the dominant high-value crop of the region; 3. the impacts of exogenous changes lead to both allocative and dynamic feedback; and 4. predicting the likely impacts of severe droughts in terms of magnitude, direction, and timing of resource transfers facilitates short-term economic planning.

Introduction

Over the past three decades, agricultural production in India has, in general, failed to accelerate. The production of food grains has barely surpassed the needs of a rapidly increasing population. Despite the technological change that took place during the mid-1960s, the growth rate in agricultural production declined when compared to that in the 1950s (Rao, 1975). In the earlier period, much of the increase in production was attained through area expansion; during the latter period, land under cultivation reached a level of stagnation. Even the little productivity growth achieved through technological change–called the green revolution– was confined to a few pockets such as Punjab, Haryana, parts of Uttar Pradesh and Rajasthan, with relatively high percentage area under irrigation where high-value, moisture-intensive crops such as wheat and paddy were grown. This technological change was characterised by HYV seed and intensive use of chemical fertilisers. The last two decades also saw spectacular improvements in irrigation infrastructure bringing benefits to more than half of the gross cropped area in some of the states (Jose, 1977).

Thus, whatever little increase in agricultural production that India achieved during the first or second decade after independence is, by and large, owing to area expansion or irrigation development, but not productivity growth. Against this background, both planners and irrigation experts now feel that a point of saturation has been or will soon be reached for area expansion and irrigation development by themselves to increase agricultural production. Under these

circumstances, the only hope to feed the ever-increasing population is to divert research efforts to the development of dryland agriculture through appropriate techologies based both on crops and on farming systems. It is estimated that about 46% of cultivated area will be rainfed even in 2000 A.D. (Singh, 1983). Towards this goal, institutions such as ICRISAT have a major role to play. When it comes to crop specificity, the emphasis should be on the slow-growth, low-value, rainfed crops–coarse cereals, pulses and oilseeds. Traditionally, farmers (and policymakers) have neglected these crops because of their low productivity and relatively low net return. They argue that low productivity is in fact owing to their low resource use, as these crops are grown only on marginal lands with little or no inputs, and under adverse climatic conditions. They also argue that the producers of these crops are too poor to make considerable investments to raise the productivity of these crops which they eventually consume (Jodha and Singh, 1982; Jodha, 1983), thus constituting a vicious circle.

Some analysts claim further that significant increase in the productivity of rainfed crops, particularly coarse cereals, would not increase crop production because of low supply response to price incentives from the producers of these crops on the one hand, and steep decline in prices owing to negligible demand response from the consumers on the other. As these arguments are impressionistic, and evidence on the demand and supply aspect of these rainfed crops is sketchy, there is an urgent need to look into these aspects more closely. Unlike in irrigated agriculture, crop diversity is a notable feature of dryland farming and hence the need to quantify farmers' production decisions in an integrated systems approach. Besides, since a majority of farmers growing these crops are producer-consumers, there is need to link both supply and demand for these crops. Such an approach would help in simulating impacts of certain exogenous changes in rainfall distribution, productivity growth, and any other behavioural/policy parameters. These impacts would have both allocative and dynamic feedbacks through income prices, etc. The usefulness of such an analysis cannot be overemphasised as it provides directions for research and policy action.

In earlier exercises, Behrman and Murty (1983; 1985) hav developed a methodology to perform such scenario simulations an applied the same successfully to analyse semi-arid tropical (SAT) crop markets. Their results give useful insights into the functioning of agricultural markets in an underdeveloped region such as the SAT, and indicated the need to regionalise the model for capturing interregional differences in cropping pattern, environmental variability, etc. In this paper we try to bring in more empirical support to the earlier findings and throw some light on the regional dimension. The paper is organised as follows: In the next section we briefly discuss the simulation methodology. We then deal in some detail with the data for quantifying demand/supply parameters used by ICRISAT and their collaborators, and analyse their utility. Following this, we discuss the base simulation that serves as reference to all other scenario simulations. We go on to discuss the rainfall shortage and productivity increase scenarios. Lastly, we list the conclusions and limitations of this study.

Methodology

The simulation methodology consists of piecing together information on the two counteracting forces of demand and supply of the market phenomenon—hitherto treated separately in empirical analyses—into a general equilibrium framework, and enables us to study the impact of certain exogenous changes. Such a joint study of the 'push' and 'pull' factors of the market is essential for a complete understanding of its functioning.

This requires good knowledge of the technical and behavioural considerations underlying supply and demand which, in turn, require an abstraction of the complex reality. In this section, we outline the theoretical formulations of demand, supply and the intricacies of the simulation methodology.

Following the methodology given in Behrman and Murty (1983; 1985), the deterministic part of the basic output supply/factor demand model for an observation can be represented in vector notation as:

$$S = f(P^*, X) \quad \dots (1)$$

where S is an m element vector of quantities consisting of m_s

number of crop outputs and m_i number of variable factor inputs such that $m = m_s + m_i$.

P^* is an m_s vector of expected output prices, one element corresponding to the first m_s elements of S.

X is an m_x element vector of other variables, including m_i factor input prices and m_a additional non-purchasable/fixed variables such that $m_x = m_i + m_a$.

An equivalent representation of (i) in growth rate form is:

$$\dot{S}_i = \sum_{j=1}^{m_s} \beta_{ij} \dot{P}_j^* + \sum_{j=1}^{m_x} \gamma_{ij} \dot{X}_j \quad \dots (2)$$

$$i = 1, 2, \dots m$$

where β_{ij} ($i = 1,2...m$, $j = 1,2,...m_s$) is the crop output supply or factor input demand elasticity with respect to expected output price; γ_{ij} ($i = 1,2...m$, $j = 1,...m_x$) is the crop output supply or factor input demand elasticity with respect to input factor price or additional variables, and a dot on the top of a variable indicates its growth rate.

Thus, equation (2) states that the growth rate ($\dot{S}_i$) in output supply/input demand for a particular crop/factor is a linear combination of growth rates of all expected prices ($\dot{P}$) and all additional variables ($\dot{X}$). Equation (2) also regards β_{ij}, γ_{ij}, the output supply/factor demand elasticities, as constants, whereas in reality they may depend on the overall configuration of all expected prices and other variables.

One essential feature of the formulation (2) is its ability to incorporate cross-crop/factor interactions in supply and resource use, which is crucial to diversified agriculture as that prevailing in the SAT. In addition, all the estimates, as they appear in (2), together form a consistent set of parameters, unlike in single equation models, and underlie a rational behaviour (e.g., profit maximisation) by the decision-maker (farmer). These latter aspects of theoretical consistency are essential for such a model to form part of a general equilibrium framework.

In a parallel way, the basic output demand model for a single observation can be represented in vector notation as:

$$D = g(P^d, Y) \qquad ...(3)$$

were D is n element vector of output quantities demanded; P^d is n element vector of output prices, and one element corresponding to each element of D and Y is the consumer's income or total expenditure, its proxy.

In growth rate form (3) can be written as:

$$\dot{D}_i = \sum_{j=1}^{n} \delta_{ij} \dot{P}^d_j + \delta_{io} \dot{Y} \qquad ...(4)$$

$$i = 1,2,...,n$$

where D_i is the growth rate in ith quantity demanded, P^d_j is the growth rate in jth price and Ys growth rate in income. The parameters δ_{ij}'s are output demand elasticities with respect to output prices and consumer income.

The observations made for the supply model are equally valid here. The aggregate supply of, and demand for, any commodity in a region can be viewed as consisting of several individual components such as domestic/regional production, net imports on the production side and consumption demand, livestock demand, seed reserves, inventories by government, traders, consumers, and losses on the absorption side. Although theoretically several or each of these variables might respond to overall market structure, it may not be feasible to study them individually in practical applications, owing to paucity of data. In our case too, we make certain assumptions regarding these unobservable components although it is possible to relax these assumptions as a simulation hypothesis by itself (e.g., Behrman and Murty, 1983; 1985). More specifically, we assume approximate proportionality between components on production as well as absorption sides. This gives us the following relation:

$$(1-a_i) S_i = (1+b_i) D_i \qquad ...(5)$$

where a_i, b_i are constants, specifitc to each commodity/crop. In growth rate form, (5) becomes:

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

Thus, relation (6) is the basic equation that ties the forces of supply and demand, using which we can calculate growth rates in prices by substituting (6) in (4) or (2) and solving for the unknowns. It should be noted that relation (6) is appropriate only in the case of commodities that are produced and consumed in their raw form, with little or no processing. Since this is true in the case of underdeveloped agriculture in general and food commodities in particular, we may be justified in using it for ICRISAT's mandate crops. As already mentioned, any deviations from this assumed 'normal' behaviour are treated as separate simulation hypothesis against the base simulation. These include simulations like productivity changes, inventory behaviour, trade, etc. For commodities which are not comparable on the demand and supply sides, the only option is to compute the rates of change in their demand and supply quantities, given their respective prices. This would also apply to commodities that are sparingly produced in a region but consumed substantially by its population through imports. The prices of such commodities are determined outside the region of concern.

Even for commodities that are regionally produced and consumed, it is obvious that the prices paid by consumers are different from what the producers receive for their output. The differences are attributable to transportation, processing, and trade margins. If we assume that these costs constitute a fixed proportion of producer price, say θ, then we have a relation:

$$P^d_i = \theta_i P_i \ ... (7)$$

In growth rate form (7) can be rewritten as:

$$\dot{P}^d_i = \dot{P}_i \ .... (8)$$

which links the producer and consumer prices for any commodity.

The exceptions mentioned in the case of relation (6) apply for (8) as well. Thus, relations (2), (4), (6) and (8), together with a formula for expected prices and known elasticity coefficients, constitute a complete set of equations for a price determination model in growth rate form. Given the levels of the endogenous prices and quantities for some base year, the levels of the variables can be generated for successive years.

In underdeveloped agriculture like that prevailing in SAT areas, a substantial part of food grain production is being consumed by producers themselves. Thus, any change in revenue of the producers also affects their consumption basket. This brings in another link between demand and supply, other than through prices. To quantify this relationship, the income of the producer-consumer is assumed to consist of two parts: (a) value added from crop production; and (b) income from non-crop activities, including animal husbandry. This can be written as:

$$Y = c\left(\sum_{i=1}^{m_s} S_i P_i - \sum_{i=m_s+1}^{m} S_i P_i\right) + Y_o \qquad \text{... (9)}$$

Where c is the value added parameter out of crop production and Y_o is non-crop income. The expression within parentheses on the R.H.S. of (9) is net revenue after deducting the costs of all purchased inputs. The value of c depends on various factors including agriculture-industry linkages. Ali et al. (1980) have estimated the c value to be 0.856 in nonirrigated agriculture in India. They also estimated that the average income from livestock and non-crop activities is about 9% of the value added from crop production.

To summarise, the simulation methodology involves the following steps:

Step 1. Given the supply response parameters (elasticities), past prices and other exogenous variables, the current rates of change in output supply and factor demand are determined using relation (2).

Step 2. Using these newly generated output supply/input demand quantities, and a set of assumed prices, the producer-consumer's income is determined using relation (9).

Step 3. Given the consumer demand parameters (elasticities), computed income and current rates of change in output supply—which are equated to rates of change in output demand in view of relation (6) --the rates of change in an improved set of output prices can be calculated for all items for which markets are assumed to be cleared. For items whose prices are set outside the region, the rates of change in their quantities demanded are computed. Steps 2 and 3 are repeated until the endogenous variables do not change by more than a pre-fixed numerical error. This gives us the simulated values of endogenous variables for that year. Having obtained them the procedure is repeated from step 1 onwards for next year.

There are two sources of dynamism in this simulation process: (1) the expected price generation mechanism using lagged prices; and (2) using estimated lagged values of the endogenous variables, instead of observed values, in successive time periods. Thus, the simulation model is recursive dynamic. In the following section, we describe the data used by ICRISAT staff and their collaborators for estimating supply-demand parameters that are crucial for the simulation process. We also discuss certain salient features of the estimated parameters.

Data and Parameterisation

Supply Module

For the estimation of supply response parameters, such as those in relations (2), district-level data have been assembled for 93 districts belonging to the semi-arid tropical (SAT) states of Andhra Pradesh, Karnataka, Madhya Pradesh, and Tamil Nadu for the period 1956/57 to 1978/79. Data were gathered from published sources, such as Season and Crop Reports, State Statistical Abstracts, and unpublished information obtained from state agriculture and marketing directorates. The data collected covered 22 major crops and included information by district on production, area, farm harvest prices, rainfall, fertiliser use, etc.

After examining this massive data set in terms of indicators like cropping pattern, and environmental variability, Bapna, Binswanger and Quizon (hereafter BBQ), have identified 14 agro-climatic subregions and further grouped them into three cropping zones, called RICE SAT, WHEAT SAT and COTTON-GROUNDNUT SAT. A fourth zone called ALL SAT encompasses all the three cropping zones (Bapna, Binswanger, and Quizon, 1984).

SAT wheat is primarily non-irrigated wheat grown in Madhya Pradesh during the winter months on deep Vertisols using residual moisture. SAT rice is mostly grown during summer months under irrigated conditions in Andhra Pradesh and Karnataka. Cotton and groundnut are more widely grown in the SAT than rice and wheat. Crop aggregates were formed, consistent with the above crop zoning and manageable in number for supply-response estimation.

After making suitable transformations for pooled time series of cross-sectional (subregional) data, BBQ estimated six sets of supply response parameters, using the systems of output-supply/ factor demand approach[1]. The six sets differ in their geographical coverage and commodity aggregation. All the systems were estimated with two underlying profit function assumptions–Generalised Leontief and Normalised Quadratic Functional Forms. Based on empirical considerations, BBQ recommended systems based on normalised quadratic functional forms. For our analysis, we choose their estimates based on system A for ALL SAT, system B for WHEAT SAT, and system C for RICE SAT zones.

In addition to the expected output prices and input factor costs as explanatory variables, each of the above systems included five additional infrastructural variables: annual rainfall, extent of use of high-yielding varieties of rice, wheat, sorghum, pearl millet, and maize; road density; regulated market density; and extent of irrigation. Appendix Table 1 gives definitions of variables, units of measurements, mean and coefficient of variation values, and annual percentage (compound) growth rates over the simulation period 1966-78 by crop zones. This table indicates the relative position of each cropping zone with respect to production, farm harvest prices, as well as other infrastructural variables.

TABLE 1: Crop-output supply and factor-input demand elasticities.

	SUPCERP	JOWARP	OCRSCERP	PULSESP	OILSEEDP	OCROPSAP	FERTP	WAGE
ALL SAT								
SUPCERQ	0.359	0.002	-0.118	0.014	-0.166	-0.043	0.025	-0.075
JOWARQ	0.005	0.354	-0.034	0.145	-0.088	-0.056	0.034	-0.360
OCRSCERQ	-0.358	-0.044	0.388	-0.202	0.177	0.215	0.073	-0.249
PULSESQ	0.062	0.263	-0.285	0.786	0.028	-0.136	-0.398	-0.320
OILSEEDQ	-0.390	-0.087	0.137	0.016	0.236	0.078	-0.089	0.100
CROPSAQ	-0.076	-0.043	0.126	-0.057	0.059	0.156	-0.048	-0.118
FERTQ	-0.247	-0.140	-0.236	0.911	0.373	0.263	-1.068	0.145
LABORQ	0.054	0.110	0.059	0.054	-0.031	0.048	0.011	-0.305
WHEAT SAT	WHEATP			BGMP		OCROPSCP		
WHEATQ	0.569	-0.443	-0.049	0.034		-0.125	-0.147	0.164
JOWARQ	-0.487	0.995	0.014	-0.094		-0.359	0.105	-0.173
OCRSCERQ	-0.136	0.036	0.449	-0.397		0.276	0.031	-0.260
BGMQ	0.082	-0.208	-0.344	0.769		-0.253	0.037	-0.080
OCROPSCQ	-0.067	-0.174	0.053	-0.056		0.337	-0.015	-0.080
FERTQ	1.745	-1.136	-0.132	-0.183		0.345	-0.749	0.080
LABORQ	-0.179	0.172	0.101	0.036		0.163	0.007	-0.301
RICE SAT	RICEP				GNUTQ	OCROPSDP		
RICEQ	0.708	-0.084	-0.112		-0.027	-0.260	-0.021	-0.205
JOWARQ	-0.454	1.042	0.070		-0.113	-0.032	0.159	-0.668
OCRSCERQ	-0.418	0.049	0.529		-0.106	0.142	0.080	-0.271
GNUTQ	-0.102	-0.079	-0.106		0.815	0.049	-0.062	-0.519
OCROPSDQ	-0.571	-0.013	0.083		0.029	0.240	-0.020	0.255
FERTQ	0.254	-0.357	-0.258		0.201	0.109	-0.355	0.401
LABORQ	0.142	0.086	0.050		0.096	-0.081	0.023	-0.317

For definition of abbreviated variables, see Appendix Table 1.
Source: Normalised quadratic profit function estimates evaluated at sample means contained in Table 5 in Bapna et al. 1984, after adjusting for fulfilment of convexity.

Table 1 summarises the implied output supply-factor demand elasticities (at the sample means) for the three cropping zones-ALL SAT, WHEAT SAT, and RICE SAT. These estimates were obtained by modifying BBQ estimates for the fulfilment of convexity conditions. The numerical approximations involved in making convexity adjustments to these parameters preclude us from establishing or rejecting their statistical significance. In spite of this limitation, it is interesting to find fairly substantial supply response to (expected) prices in these relatively underdeveloped agricutural regions.

The own-price supply elasticities for less commercial crops like sorghum range from 0.35 to 1.04 and for other coarse cereals from 0.39 to 0.53. It is somewhat puzzling to notice that 'more commercial crops' like oilseeds and pulses too have similar or even smaller supply elasticities. There are quite a few cross-price elasticities as large as own-price responses implying intercrop substitution/complementary relationships and justifying systems of equations approach. The estimates also indicate a fair amount of variation across cropping zones.

In general, all other crops, with the exception of pulses, compete with the dominant crops, rice or wheat, in all the regions. The competition is less, however, in the case of oilseeds and other crops. In spite of statutory fixation of fertiliser price, its input demand is fairly price responsive. Some of the positive signs for output supply response with respect to fertiliser price–although small–are perverse, reflecting the inadequacy of fertiliser data, and can perhaps only be interpreted as more efficient use of chemical fertiliser in the event of a hike in its price. It may also mean substituting cheaper organic manures for chemical fertilisers, data on which is not available. The output supply responses with respect to wage rate and the input demand for labour with respect to output prices are, in general, small and are of the correct sign except in a few cases.

Table 2 contains supply response parameters (elasticities) with respect to rainfall variable, for the system of our interest abstracted from BBQ. From Table 2, we observe that increased rain causes shift from sorghum to superior cereals and pulses in the ALL SAT region, and from coarse cereals to wheat and chickpea in the WHEAT SAT region.

Demand Module

For the estimation of demand parameters like those in relations (4), we need a suitable model which allows substitution among consumer items. Earlier studies (Radhakrishna et al., 1979; Radhakrishna and Murty, 1980), on Indian consumption patterns revealed that the Linear Expenditure System (LES) provides a reasonable fit when the range of income variation is small.

Consumption data used in the above studies for the estimation of the demand model are the time-series of cross-sectional data on consumer expenditure published in the reports of the National Sample Survey Organisation (NSSO) for the rounds 2 through 25 covering the period 1950-51 to 1970-71. Each of the NSSO reports on consumer expenditure provides the per capita monthly expenditure on cereals; milk and milk products; edible oils; meat, eggs and fish; sugar and jaggery; other food; clothing; fuel and light and other non food for 12/13 expenditure classes in each round. In certain of the rounds, a further breakdown of two commodity aggregates–namely cereals into rice, wheat, sorghum, pearl millet, and other coarse cereals; and other food into chickpea and other pulses–is also provided. In order to utilise this published information fully, Murty (1983) resorted to a hierarchical estimation [for similar exercises see Deaton (1975), de Haen et al. (1982)], wherein the LES demand system is estimated for aggregate commodities. Some of these aggregate commodities are then decomposed into individual items through estimation of submodels.

In order to overcome the unattractive property of linear income effects implied by the LES model, the NSSO expenditure classes have been stratified into five expenditure groups separately for rural and urban areas on the basis of the monthly expenditure classes of the 17th round 1961-62; a separate model has been estimated for each expenditure-group using the time-series of cross-sectional data. For our simulations we utilise the elasticity estimates (at the sample means) 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 (See Murty, 1983 for more details). To focus attention on ICRISAT mandate crops and also to study their substitutability/complementarity

TABLE 2 : Output supply and input demand elasticities with respect to the additional variables.[1]

	RAIN	HYK	IRK	ROADL	MKTS
			ALL SAT		
SUPCERQ	.3195***	.0675***	.3214***	.1787***	.0710**
JOWARQ	-.1998***	-.0307***	-.0292	.0413	.0468
OCRSCERQ	-.0869	-.0606***	.1736	.0810	.1325***
PULSESQ	.2565***	.0852	.0967	-.1894**	-.0239
OILSEEDQ	.0715	.0352	.3000**	-.6758***	-.3507***
OCROPSAQ	.1579	.1665**	.2227	.7473***	-.0765
FERTQ	.2229	.2411***	.3054	1.0387***	.3669***
			WHEAT SAT		
WHEATQ	.5056***	-.0499	.3110**	-.2412	.0985
JOWARQ	-.0641	-.0498	.2674	.3372*	-.1066
OCRSCERQ	-.3090*	-.1104***	.5125***	1.4228***	.0097
BGMQ	.2997***	-.0377	.2722*	-.2203	-.0519
OCROPSCQ	.0039	-.1079***	.5680***	1.0446***	-.1712*
FERTQ	.3598	-.0599	1.5297***	4.4378***	.0165
			RICE SAT		
RICEQ	.7715***	.0534***	-.1760	.0893	.0586
JOWARQ	-.0120	-.0507***	-.1810	.0224	-.0605
OCRSCERQ	.0378	-.0456**	-.0598	.0507	-.1015
GNUTQ	.1637	-.0050	.4065*	-.8226***	.3379***
OCROPSDQ	.0888	.2069***	.2770	.1127	-.1388**
FERTQ	.2204	.2688***	.4514	.9174***	.1326

For definition of abbreviated variables, see Appendix Table 1.

1. The corresponding derivatives from which these elasticities are derived are significant at these defined levels.

*** Significant at .01 level.
** Significant at .05 level.
* Significant at .10 level.

Source: Bapna et al., 1984.

to other crops and products being consumed rather comprehensively, we aggregated this detailed commodity model into three different sets of commodity aggregates with close resemblance to the three output supply systems for ALL SAT, WHEAT SAT, and RICE SAT. The 'other commodities' category on the demand side, however, cannot possibly be compared with 'other crops' category on the supply side for obvious reasons. The sets of estimates are labelled model A for ALL SAT, model B for WHEAT SAT, and model C for RICE SAT, and are presented in Table 3.

The three sets of demand elasticities do not reflect the real differences that exist in the different cropping zones because the three models are derived from the same set of estimates. In fact, one would expect taste differences across regions. In our future exercises, we might be able to incorporate regional specificity in demand parameters as well. The following observations are thus conditional upon this limitation.

Quite a few of the demand parameters are numerically large and emphasise the importance of quantifying consumer behaviour in development planning and market-oriented studies. Since these estimates are obtained through a utility maximisation procedure, they satisfy all the theoretical properties including convexity conditions.

From Table 3, all the own-price elasticities of demand are negative and the total-expenditure (income) elasticities are positive, implying that all the commodity aggregates are normal goods. The absolute values of own-price elasticity estimates for basic comsumption items are somewhat 'high'; a few of them, close to or even exceeding 2, show very little price flexibility and immense scope for supply absorption, provided the consumers have adequate purchasing power. Consequent to supply shifts, however, price adjustments in the opposite direction are inevitable.

Base Simulations

We describe the base simulation obtained by applying the methodology of earlier sections, which serves as a reference point to all the scenarios to be discussed in the next section. It is necessary to have such a base simulation as a reference point, because the impact of exogenous changes could get confounded with stochastic errors resulting from inadequacies of ex-post model description. Thus, it is imperative to tune the base simulation by re-estimating some of the parameters, choosing the appropriate starting point (base data), imposing certain product and area-specific market features, etc. It may also be necessary at times to adjust the (base) levels of certain variables to avoid systematic upward/downward predictions inherent in a systems approach to estimate supply/demand. In fact, all these modifications are imbedded in the base simulations that follow.

TABLE 3 :Output demand elasticities for the rural low-income consumer group.

Commodity group	SUPCERP	JOWARP	OCRSCERP	PULSESP	EDBOILSP	OTHCOMSAP	INCOME
				MODEL A			
SUPCERQ	-1.268	0.184	0.185	-0.008	-0.010	-0.033	0.950
JOWARQ	0.759	-1.939	0.202	-0.009	-0.011	-0.036	1.035
OCRSCERQ	0.516	0.137	-1.317	-0.006	-0.008	-0.025	0.703
PULSESQ	-0.091	-0.016	-0.067	-0.911	-0.011	0.081	1.016
EDBOILSQ	-0.077	-0.013	-0.056	-0.007	-0.669	-0.030	0.852
OTHCOMSAQ	-0.105	-0.018	-0.077	0.003	-0.013	-0.957	1.168
				MODEL B			
	WHEATP				BGMP	OTHCOMSCP	
WHEATQ	-2.093	0.211	0.181		0.031	0.583	1.087
JOWARQ	0.148	-1.939	0.172		0.030	0.555	1.035
OCRSCERQ	0.099	0.134	-1.315		0.020	0.370	0.691
BGMQ	0.113	0.153	0.132		-1.611	0.423	0.790
OTHCOMSCQ	0.046	0.060	0.020		0.006	-1.181	1.049
				MODEL C			
	RICEP				EDBOILSP	OTHCOMSDP	
RICEQ	-1.365	0.179	0.180		-0.010	0.092	0.923
JOWARQ	0.611	-1.939	0.202		-0.011	0.103	1.035
OCRSCERQ	0.415	0.137	-1.317		-0.008	0.070	0.703
EDBOILSQ	-0.069	-0.013	-0.056		-0.669	-0.044	0.852
OTHCOMSDQ	-0.006	0.009	-0.042		-0.012	-1.094	1.145

For definition of abbreviated variables, see Appendix Table 1.
Source: Linear Expenditure System estimates evaluated at sample means contained in Murty (1983), after suitable reaggregation. The estimates correspond to second rural expenditure group.

It is clear from earlier discussion in this paper that the data used for estimating supply and demand parameters have several differences. The inputs come from different sources of observation, units of data collection, etc., and cover different periods as well as geographical areas. In fact, there are more differences than similarities in the two data sets. For this reason, in spite of many simplifying assumptions, it is next to impossible to match rates of changes, not to think of levels, in commodities supplied and demanded in any particular year. One is left with no other option than to stick to one of the two data sets for evaluating the (simulation) tool and possibly extrapolate its future use. Based on these considerations, it is felt that the production data used for estimating the supply component of the model is a better choice for this purpose.

After experimenting with various starting points, we decided to use the data for 1966-68 as base information and 1969-78 as the simulation period[2]. Thus this data set overlaps with that used for estimating the supply component. The geographical coverage is the same: the four SAT states of Andhra Pradesh, Madhya Pradesh, Karnataka, and Tamil Nadu excluding the wet, as well as irrigated (by major irrigation projects) districts, from the sample. These four 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), oilseeds (37.4, 35.0), and other crops (27.1, 28.2).

The original district data is transformed in exactly the same fashion as that in the supply model to get Fischer's chained quantity and price indices (adjusted for interregional variation in base year 1956/57) and aggregated to regional level–ALL SAT, WHEAT SAT, and RICE SAT–time-series. Appendix Table 1 contains certain characteristics of this data.

Interregional differences in cropping pattern can be clearly seen from this table. Broadly, output prices are more volatile than output supplies in each of these three regions. Wheat production has grown more rapidly than rice production and wheat prices registered a less rapid rise than rice prices. Sorghum (in WHEAT SAT) as well as groundnut (in RICE SAT) registered negative growth. Coarse cereals (other than sorghum), constituting mainly pearl millet, and pulses have also shown impressive growth, but their prices have risen much faster than production. In view of the data being volatile, the task of tracing fluctuations in output quantities and prices through an econometric model is extremely difficult.

Based on the percentage share of production and acreage, it can be said that for sorghum, other coarse cereals, pulses, and oilseeds, the net trade into this region (from rest of India) is relatively small and hence it is perhaps reasonable to assume their prices are determined within the region. For rice, wheat, and cash crops, prices might be set in those regions in India where these crops are predominantly grown, and the SAT farmers would respond to those prices. In the case of fertiliser, its price is statutorily fixed by government, while non-availability of data on labour force demand/supply do not allow us to determine wage rate within the model. The effects of fertiliser price as well as the wage rate are included in the model as additional variables.

In the case of the ALL SAT model, the possibility of selling oilseeds in the rest of India is taken into account, and its demand elasticity is adjusted accordingly. These assumptions and trend adjustments in levels of certain variables have yielded fairly good description of historical data (i.e., base data).

Two summary measures of goodness of fit are calculated and presented in Table 4. These are Mean Absolute Percentage Error (MAPE) and Root Mean Percentage Error (RMPE). MAPE is calculated for the first five-year period, 1969-73, as well as for the decade 1969-78; RMPE is calculated only for 1969-78.

A cursory look at Table 4 shows that both MAPE and RMPE are, in general, larger for output prices and output demand quantities than for output supply quantities[3]. This is expected because within a year, given output supply/input demand quantities, short-run equilibrium forces prices to adjust in the case of sorghum, other coarse cereals, pulses and oilseeds; similarly, demand quantity adjustments are possible for rice, wheat, superior cereals, and other commodity categories, since their prices are fixed outside the model. The summary measures are lower for labour input demand and ex-

penditure variables. In the case of expenditure, the low value might be from annulment of positive and negative errors for prices and quantities. The MAPE values are mostly lower for the five-year period 1969-73 than for the whole decade 1969-78. This shows that there is considerable error inherent in the model and cautions extrapolation far into the future.

Across the models, the one for RICE SAT seems to be marginally better than that for WHEAT SAT in predicting output supplies; the converse is true for output prices and output-demand quantities. Examination of observed and predicted values as plotted shows that the models could reasonably trace the turning points, particularly during the first 5-year period[4]. The exceptions, however, are sorghum and other coarse cereals in all the three cropping zones, and oilseeds in the ALL SAT region. The predictions of output prices for other coarse cereals and oilseeds in ALL SAT region are also bad. In many cases, the predictions for 1974, a disastrous year, are dismal. The year 1974 had a normal rainfall (about 750-800 mm), with heavy rain (above 1000 mm) in the preceding and following years. The output of several crops–such as rice, wheat, and oilseeds–for 1974 suffered a steep decline, but the decline was not as steep for some crops like sorghum.

Scenario Analysis

All the scenario simulations that we will be discussing have the base simulation (values for endogenous variables) as reference for reasons already mentioned. The impacts of changes are all percentage deviations of the simulated path from the base path, with the latter as reference. We will be considering two types of scenarios–one in which there is an explicit exogenous variable whose development is altered and its impact studied (e.g., rainfall) and another, which does not have an explicit variable in the model (e.g., productivity change). Simulated changes in either type could be for one period (i.e., a shock) or multiperiod (i.e., sustained). In each case and for each region, we study the allocative and dynamic effects of the postulated change on aggregate production, prices, consumption of various crops, and value added from agriculture within that region.

TABLE 4 : Summary measures of percentage errors in base simulations.

	ALL SAT MAPE		ALL SAT RMPE	WHEAT SAT MAPE		WHEAT SAT RMPE	RICE SAT MAPE		RICE SAT RMPE
	1969-73	1969-78	1969-78	1969-73	1969-78	1969-78	1969-73	1969-78	1969-78
Output supply									
RICEQ							3.97	6.43	8.56
WHEATQ				10.49	10.76	13.91			
SUPCERQ	7.67	7.88	9.34						
JOWARQ	8.38	8.82	9.50	13.40	20.48	24.22	10.16	9.47	11.59
OCRSCERQ	9.25	13.40	17.11	12.49	12.04	13.73	7.66	15.28	19.58
BGMQ			13.48	12.78	15.25				
PULSESQ	10.47	11.20	12.78						
GNUTQ							9.18	14.05	21.09
OILSEEDQ	17.05	23.34	26.80						
OCROPSAQ	6.63	7.54	8.55						
OCROPSCQ				9.89	14.28	17.09			
OCROPSDQ							5.81	6.44	7.46
Input demand									
FERTQ	10.24	30.15	37.05	9.67	23.47	37.87	13.28	14.98	19.08
LABORQ	1.58	2.00	2.28	1.08	1.92	2.46	1.02	4.16	5.475
Output prices									
JOWARP	4.85	14.75	20.05	7.69	15.00	19.00	9.68	26.70	35.93
OCRSCERP	15.04	27.39	33.94	7.81	16.18	20.[illegible]8	24.60	43.51	53.02
BGMP				16.82	14.43	18.[illegible]2			
PULSESP	14.06	20.79	25.19						
GNUTP							15.40	12.71	14.33
OILSEEDP	14.82	14.33	16.01						
Output demand									
RICEQ						6.13	13.78	16.46	
WHEATQ				21.89	20.3[illegible]	24.72			
SUPCERQ	14.24	17.51	19.32						
OTHCOMSAQ	27.09	165.16	235.88						
OTHCOMSCQ				20.41	19.84	23.22			
OTHCOMSDQ							22.16	78.97	99.68
Expenditure	5.35	5.67	7.45	3.39	10.20	13.48	3.92	5.41	8.01

MAPE = Mean Absolute Percentage Error; RMPE = Root Mean Percentage Error.

For definition of abbreviated variables, see Appendix Table 1.

From the way the crop aggregates were formed and included in different models, it happened that only two crop aggregates: 1. sorghum and other coarse cereals, and 2. two input factors–fertiliser and labour (implicitly included)–apear in all models. Thus, only for these crop supplies/input demands, direct comparison of impacts across cropping zones is possible. Similarly, the derived expenditure variable, value added from agriculture, can also be compared across zones. In the case of other variables, however, we can compare allocative and dynamic effects within a cropping zone. The following scenarios are being explored here:

A. Induced shortfall in rain by 30% in 1969.
B. Induced shortfall in rain by 30% in 1969 and 1970.
C. Increase in sorghum productivity by 25% spread over 1969-77.
D. Increase in productivity of all mandate crops– sorghum by 25%, other coarse cereals (mainly pearl millet), pulses, and oilseeds–each by 10%.

A. Rainfall Shortage (Drought) in 1969

In this scenario, the observed rainfall in 1969 is reduced by 30% and the model simulates endogenous variables for 1969-78. The percentage deviations of the endogenous variables from base simulation values are presented in Table 5 separately for each cropping zone. It should be pointed out that the models incorporate only annual rainfall as a variable, and this may not adequately represent the weather effects on crop production. The timing of rainfall, rather than the aggregate amount, is at least equally important in crop production. To this extent the effects reported here might underestimate the impact of drought on crop production, and the discussion is subject to these limitations.

The impacts of a year-long drought on crop production in 1969 are roughly proportional to the rainfall responses reported in Table 2 for the ALL SAT region. In 1969, owing to the induced shortage in rainfall, the output supplies of superior cereals, pulses, oilseeds, and other cash crops declined, while those of sorghum and other coarse cereals went up. Since the production of most fertiliser using crops was lower, the input demand for fertiliser declined. These changes

TABLE 5 :Scenarios of percentage in variables caused by 30% induced shortfall in rain in 1969.

	ALL SAT			WHEAT SAT			RICE SAT		
	1969	1970	1974	1969	1970	1974	1969	1970	1974
Output supply									
RICEQ							-22.32	3.54	1.69
WHEATQ				-17.77	1.30	-1.26			
SUPCERQ	-10.58	1.36	0.60	2.48	-4.16	-0.27	0.42	-6.34	0.44
JOWARQ	8.14	-1.71	-0.58	14.20	-3.07	1.32	-1.45	-2.28	0.88
OCRSCERQ	3.48	-2.72	-0.31	-10.57	6.42	0.09			
BGMQ									
PULSESQ	-9.50	2.14	-1.41				-5.14	-2.17	0.51
GNUTQ	-2.98	-0.40	-0.11						
OILSEEDQ	-5.51	-0.38	0.21						
OCROPSAQ				-0.16	0.10	0.02	-3.00	0.17	0.76
OCROPSCQ									
OCROPSDQ									
Input demand									
FERTQ	-7.99	3.95	-2.54	-12.00	1.05	-3.30	-6.37	4.31	1.31
LABRQ	0.00	-0.66	-0.03	0.00	-1.57	0.01	0.00	-1.50	-0.03

(contd.)

(contd.)

TABLE 5 :Scenarios of percentage in variables caused by 30% induced shortfall in rain in 1969.

	ALL SAT			WHEAT SAT			RICE SAT		
	1969	1970	1974	1969	1970	1974	1969	1970	1974
Output prices									
JOWARP	-7.07	0.81	0.21	-5.44	2.98	-0.07	-8.39	5.14	0.27
OCRSCERP	-5.87	1.74	-0.11	-11.54	5.78	0.55	-6.96	4.23	0.72
BGMP				3.08	-2.26	0.33			
PULSESP	5.38	-3.68	-0.10						
GNUTP									
OILSEEDP	-0.99	0.06	0.11				-10.50	3.82	-4.06
Output demand									
RICEQ							-15.23	2.04	-0.52
WHEATQ				-10.10	-1.52	-3.67			
SUPCERQ	-7.45	-0.28	-0.49						
OTHOMSAQ	-13.22	3.71	3.13						
OTHCOMSCQ									
OTHCOMSDQ				-5.13	2.34	1.07	-16.38	2.32	4.82
Expenditure	-5.13	-0.21	0.09	-5.62	0.53	-0.01	-13.72	1.68	0.73

The entries are percentage deviations from base simulations.
For definition of abbreviated variables, see Appendix Table 1.

are in accordance with the signs of rainfall responses given in Table 2. The other changes need more explanation.

Owing to the decline in production of high-value crops, the value added from agriculture was lower. In the view of the producer-consumer income linkage for commodities whose production increased (sorghum and other coarse cereals), prices declined to absorb the additional output. This is essentially a downward movement along the (downward) shifted demand curves. In the case of commodities whose supply had fallen (oilseeds), and whose demand (including exports) was elastic, prices declined for the same reason. In the case of superior cereals and other commodities, their demand fell because of exogenously fixed prices and lower income. The impacts in the following year are more interesting.

Owing to lowered prices in 1969—and hence, lower price expectations for sorghum and other coarse cereals—their supply declined in 1970. For pulses, higher price expectations resulted in higher production. The increase in the supply of superior cereals is perhaps owing to the following: from the cross-price responses of superior cereals supply (Table 1), the change in the prices of pulses, sorghum, other coarse cereals, and oilseeds in 1969, all have a small but positive impact on the supply of superior cereals. So is the case with other crops, including oilseeds. Because of increased supply of superior cereals, the demand for fertiliser went up. Thus, all the effects in 1970 were comparatively smaller in absolute value than those for 1969. The consequent changes in output prices and value added are also small. These effects get reduced further in 1974 and possibly disappear thereafter.

In wheat-growing SAT regions, the impacts are similar, but vary in magnitude. Owing to induced drought, wheat production declined by 17.8%, while the supply of other coarse cereals expanded by 14.2% and production of chickpea fell by 10.6%. As a sequel, their prices also changed significantly in the opposite direction. Sorghum production expanded more slowly, at one third the rate as that in ALL SAT. The decline in value added is similar to that of ALL SAT. In 1970, the impacts were much smaller. Both wheat and chickpea production expanded in a complementary way.

in rice-growing SAT areas, there seems to be monoculture centring around rice production. The decline in rice production owing to the year-long induced drought is tremendous (22.3%), with less significant changes in other crops except groundnut, whose supply had fallen by 5.1%. The decline in value added is also more rapid–more than twice that of other regions. By 1974, all these effects get dampened. This scenario provided important insights as to the likely working of agricultural markets under severe failure of monsoon in a less-developed region. These include: (1) exogenous changes induce significant compositional shifts in production, consumption, and varied changes in prices; (2) owing to dynamic and lagged feedbacks, the impacts may persist over a longer period than when the exogenous change has been induced; and (3) most of the impacts caused by exogenous shocks would die down after some time, differently for different commodities and regions, bringing back the growth pattern to the base (simulation) path.

B. Rainfall Shortage (Drought) in 1969 and 1970

In underdeveloped agriculture, it is often said that small and marginal farmers would be severely affected and forced to sell their meagre assets like land, bullocks, etc., in the event of consecutive droughts, whereas they (farmers) may be able to withstand a year-long drought with less disastrous consequences (by selling gold, jewellery, other valuables, etc.). Though our model cannot simulate droughts of that nature, it can simulate the consequences of major reductions in rainfall in successive years.

In this scenario, we simulate a 30% reduction in annual rainfall in 1969 and 1970. The impacts of this scenario (Table 6) in 1969, are exactly the same as in scenario A. The effects of scenario B in 1970 and subsequent years need some explanation. Firstly, the impacts in 1970, another drought year, are not the same as in 1969 owing to carryover effects. They seem to be approximately equal to the algebraic sum of the effects for 1969 and 1970 in a year-long drought simulation. No such relationship can be identified for subsequent years.

To illustrate the impacts in 1970 for the ALL SAT region, the increase in the supply of sorghum and other coarse cereals is only

6.9% and 1%, respectively, over the base simulation, as against 8.1% and 3.5% in 1969 (9.5%). Similarly, the production of pulses declined at a lesser rate (7.1%) than in 1969. The supply of oilseeds and other crops decreased at marginally higher rates, 3.23 and 6%, respectively, compared to 3% and 5.5% in 1969. The supply of superior cereals declined at a lower rate (10.0%) than in 1969 (10.6%); consequently, the demand for fertiliser did not fall as much as it did in 1969. Owing to the fall in production of most of the crops, the value added from agriculture declined by 5.4%, as compared to the base simulation. The huge decline in prices could not be fully compensated by cross-price responses, which have a positive impact. These impacts declined over time as they did earlier, and almost absorbed the exogenous shock by 1974.

In wheat-growing regions, owing to induced drought in 1970, the supply of other coarse cereals went up by 9.1% instead of 14.2% as in 1969; the production was lower by 5.1% for chickpea and 15.8% for wheat, and continued to fall. Fertiliser consumption declined by 8.4% in 1970 and by 3.8% in 1974. The value added from agriculture is slightly better (-4.2%) than in ALL SAT (-5.4%), and much better than in RICE SAT (13.4%). The sharp decline in value added in RICE SAT is owing to a big drop in rice production (-21.4%), the main income source, as well as decline in other less important dry crops and their prices. In all these cases, the quantities demanded of rice, wheat, and other commodities declined because of a downward shift in the demand curves.

C. 25% Increase in Sorghum Productivity, 1969-77

The main objective of ICRISAT is to increase the productivity of all mandate crops through development of crop and farming-systems based technologies. To succeed, such an effect calls for a thorough understanding of the socio-economic environment of the region in general, and the likely macroeconomic effects in particular. Some analysts claim that significant increases in crop productivity, especially in coarse cereals, will not substantially increase output because of two reasons: 1. low (near zero) supply response from producers of such crops to price incentives; and 2 low (near zero or even negative) demand response from consumers of these outputs, which depress their prices without significantly expanding expansion in output.

The supply and demand parameters (given in Table 1 and 3), *ceteris paribus* for SAT India, refute the above contention. It remains to be seen, with the help of simulations, how the forces of demand and supply interact in the event of sizable productivity gains in mandate crops. It would be useful to quantify the net effects–both allocative as well as dynamic, after making allowance for likely (negative) market effects–of productivity change on output supply of the crop concerned as well as on other crops.

In view of these apprehensions, it would be useful to remind ourselves about the way a productivity change operates in an integrated demand/supply framework. A productivity increase of T%, for example in sorghum, would have three components: (1) output of sorghum would increase by T% with the existing level of input use; (2) as sorghum productivity increases, there would be reallocation of resources (identical to the effect of T% increase in the price of sorghum, keeping all other input and output prices unchanged); and (3) in view of these two positive effects, sorghum output expands, accompanied by adjustments in other outputs depending upon sorghum cross-price supply responses. All these output changes result in price adjustments in the opposite direction, depending upon demand responses offsetting part of the earliest changes in supply. Thus, the net effect of a productivity change on output is the sum of these three effects. If in addition there are lags in the model, these effects would have dynamic feedbacks.

In this scenario, we simulate a 25% increase in sorghum productivity spread over 1969-77. We assume an S-shaped adaptive pattern, with a maximum growth rate of 5% in 1973 and smaller increases in earlier and subsequent years[5]. The impacts of such a simulation are given in Table 7. These are reported at three points in time–for 1971, 1974, and 1978. Although the targeted 25% cumulative productivity is reached in 1977 itself, the simulated growth path would perhaps take longer than 1978 to reach a stable path. As already observed, time-series data were not available after 1978, so we could not simulate beyond 1978[6].

The magnitude and signs of impacts on various crops are in agreement with the supply responses given in Table 1 for all the three cropping zones, and for all the years. There are a few

TABLE 6 :Scenarios of percentage changes in variables caused by 30% induced shortfall in rain during 1969 and 1970.

	ALL SAT			WHEAT SAT			RICE SAT		
	1969	1970	1974	1969	1970	1974	1969	1970	1974
Output supply									
RICEQ							-22.32	-21.35	2.41
WHEATQ				-17.77	-15.77	0.16			
SUPCERQ	-10.58	-9.96	1.15						
JOWARQ	8.14	6.86	-0.80	2.48	-1.74	-0.72	0.42	-5.81	0.56
OCRSCERQ	3.48	0.96	-0.16	14.20	9.09	0.19	1.15	-3.98	0.40
BGMQ					-10.57	-5.08	0.51		
PULSESQ	-9.50	-7.07	-0.20				[illegible]	0.73	1.91
GNUTQ									
OILSEEDQ	-2.98	-3.23	0.16						
OCROPSAQ	-5.51	-6.03	0.20						
OCROPSCQ				-0.16	-0.05	0.06			
OCROPSDQ							-3.00	-3.54	0.12
Input demand									
FERTQ	-7.99	-3.75	-0.94	-12.00	-8.36	-3.80	-6.37	-4.32	0.77
LABORQ	0.00	-0.66	0.06	0.00	-1.57	-0.02	0.00	-1.50	0.26

(contd.)

(contd.)

TABLE 6 :Scenarios of percentage changes in variables caused by 30% induced shortfall in rain during 1969 and 1970.

	ALL SAT			WHEAT SAT			RICE SAT		
	1969	1970	1974	1969	1970	1974	1969	1970	1974
Output prices									
JOWARP	-7.07	-6.44	0.21	-5.44	-2.00	0.60	-8.39	-5.14	1.20
OCRSCERP	-5.87	-4.25	0.32	-11.54	-6.56	2.10	-6.96	-4.79	1.61
BGMP					3.08	1.07	-0.41		
PULSESP	5.38	1.94	-0.24						
GNUTP									
OILSEEDP	-0.99	-1.02	0.24				-10.50	-5.45	0.20
Output demand									
RICEQ							-15.23	-14.21	3.28
WHEATQ				-10.10	-7.79	-1.13			
SUPCERQ	-7.45	-7.24	0.70						
OTHCOMSAQ	-13.22	-12.09	1.41						
OTHCOMSCQ				-5.13	-3.18	0.85			
OTHCOMSDQ							-16.38	-15.96	-1.80
Expenditure	-5.13	-5.35	0.39	-5.62	-4.21	0.38	-13.72	-13.44	1.68

The entries are percentage deviations from base simulations.

For definition of abbreviated variables, see Appendix Table 1.

TABLE 7 :Scenarios of percentage changes in variables caused by a 25% increase in sorghum productivity spread over 9 years, 1969-77.

	ALL SAT			WHEAT SAT			RICE SAT		
	1971	1974	1978	1971	1974	1978	1971	1974	1978
Output supply									
RICEQ							0.34	-0.72	-0.64
WHEATQ				-1.75	-4.04	-4.12			
SUPCERQ	-0.03	-0.29	-0.34						
JOWARQ	7.19	25.70	32.64	9.40	31.97	39.57	9.76	31.52	38.63
OCRSCERQ	-0.11	-0.07	-0.05	0.06	-0.01	0.06	0.10	-0.02	-0.12
BGMQ					-0.76	-1.45	-1.09		
PULSESQ	1.05	3.15	2.85						
GNUTQ							-0.09	0.42	0.67
OILSEEDQ	-0.36	-0.61	-0.48						
OCROPSAQ	-0.15	-0.33	-0.31						
OCROPSCQ				-0.66	-1.57	-1.62			
OCROPSDQ							-0.05	-0.12	-0.12
Input demand									
FERTQ	-0.59	-0.58	-0.43	-3.34	-8.35	-8.41	-1.18	-2.50	-2.25
LABORQ	0.49	1.26	1.18	0.67	1.54	1.76	0.36	0.85	0.83

(contd.)

TABLE 7 :Scenarios of percentage changes in variables caused by a 25% increase in sorghum productivity spread over 9 years, 1969-77.

	ALL SAT			WHEAT SAT			RICE SAT		
	1971	1974	1978	1971	1974	1978	1971	1974	1978
Output prices									
OWARP	-3.04	-8.74	-11.58	-4.63	-11.49	-12.78	-4.56	-11.58	-13.76
OCRSCERP	0.11	0.38	0.00	-0.41	-0.18	1.00	-0.38	-0.56	-0.65
GMP					0.11	0.62	1.74		
PULSESP	-0.35	-0.02	-0.52						
GNITP									
OILSEEDP	0.65	2.02	1.94				0.70	1.50	1.31
Output demand									
ICEQ							-0.64	-1.21	-1.36
HEATQ				-0.73	-0.25	1.83			
UPCERQ	0.07	0.82	0.25						
THOMSAQ	-1.30	-5.30	-2.75						
THOMSCQ				-1.53	-3.71	-11.17			
THOMSDQ							0.86	0.20	0.81
penditure	0.64	2.40	2.31	0.24	1.96	4.72	0.31	1.31	1.49

e entries are percentage deviations from base simulations.
r definition of abbreviated variables, see Appendix Table1

exceptions, however. The supply of superior cereals in ALL SAT zone, and other coarse cereals and groundnut in RICE SAT zone, have opposite signs when compared with supply responses given in Table 1. This might be because of the mutually reinforcing cross-price effects in the case of superior cereals in the ALL SAT region, and own as well as cross-price effects in the case of other coarse cereals and groundnut in the RICE SAT region.

Owing to an increase in sorghum productivity, its output goes up at a higher rate than the productivity growth rate in all the three regions, the order or magnitude varying slightly. The three regions recorded sorghum output growths ranging from a low of 32.6% in ALL SAT region to a high of 39.6% in WHEAT SAT areas, with the third region falling in between (but closer to WHEAT SAT). This shows that the price decline for sorghum (11.6%, in ALL SAT, 12.8% in WHEAT SAT, and 13.8% RICE SAT) could not discourage its production more than the (positive) reallocation effect. Sorghum production seems to have a complementary relationship to production of pulses in ALL SAT region and to groundnut production in RICE SAT areas. Rice, wheat, and cash crops seem to be the main crops giving up land. The demand for other commodities suffered in both ALL SAT and WHEAT SAT areas despite increased income (and fixed prices), whereas it gained marginally in rice-growing areas. The demand for fertiliser slackened owing to decline in production of fertiliser-using crops: rice, wheat, and cash crops. Labour use has however gone up marginally. By the end of the decade, sorghum producers gained in their aggregate revenue and consumers also benefited from lower prices.

D. Productivity Increase in All the Mandate Crops

Simulation looked at individual crop productivity increases attainable through, for example, high-yielding/hybrid seed varieties. These are usually specific to the crop concerned. Such productivity increases in specific crops might benefit farmers from only certain soil types, and agro-climatic environments. Productivity changes brought about by certain technologies, for example farming systems based soil-and-water-management technology, might benefit several crops grown in a region. The benefits, however, need not be uniform postulate productivity gains for all mandate crops–sorghum, other coarse cereals (mainly pearl millet), pulses, and oilseeds–aggregating to 25% for sorghum and 10% for each of the other crops spread over 9 years. The pattern of increase is the same as in the earlier scenarios. The impacts are reported in Table 8.

Only the ALL SAT model treats all the four mandate crops separately. The other two models have either pulses or oilseeds in combination with crops from the other crops category. In these two cases, productivity increase of only sorghum, other coarse cereals, and of either chickpea or groundnut is incorporated.

Each impact in this scenario is confounded and cannot be attributed to a specific exogenous productivity change. In spite of this, one can see the joint effect on individual crops in various crop zones. The percentage changes over the base simulation given in Table 8 indicate differential effects between crops and across cropping zones. The terminal impact (in 1978) of a 10% productivity increase on output is lowest for groundnut (9.4%), and highest for pulses (13.4%).

With a 25% increase in sorghum productivity, the output growth ranged between 32.2% for ALL SAT and 38.9% for WHEAT SAT. For groundnut, the output growth is in fact less than the postulated rate of productivity increase, indicating the possibility of the (negative) market effect more than off-setting the (positive) resource allocative effect. This is further evidenced by the largest (other than pulses) decline in groundnut price in 1978.

Interestingly, the decline in rice and wheat supplies because of this joint productivity increase of other crops is only marginally higher than the decline observed in the case of individual productivity increases. This might be owing to the continued higher relative profitability of rice and wheat (because their prices are exogenously fixed) compared to the mandate crops. Similarly, because of higher relative prices of rice, wheat, and other commodities, consumers reduce their demand for these items. The increase in overall value added from agriculture is only marginal owing to joint productivity increase, thus belittling their benefit to producers. It should be pointed out that the postulated productivity increase ...

[TA]BLE 8: Scenarios of percentage changes in variables of all mandate crops[1] caused by productivity increase spread over 9 years, 1969-77.

	ALL SAT			WHEAT SAT			RICE SAT		
	1971	1974	1978	1971	1974	1978	1971	1974	1978
tput supply									
CBO							-0.53	-0.97	-0.72
HEATQ				-1.77	-4.05	-4.03			
PCERQ	-0.46	-1.15	-0.99						
WARQ	7.16	25.45	32.22	9.25	31.49	38.91	9.69	31.25	38.31
RSCERQ	2.71	9.45	11.77	2.21	8.04	10.27	3.05	9.54	11.60
IMQ					2.12	8.12	10.49		
LSESQ	3.84	12.42	13.41				2.65	8.17	9.44
UTQ	2.60	9.23	11.63						
LSEEDQ	0.05	0.11	0.05						
ROPSAQ				-0.66	-1.56	-1.59			
ROPSCQ							0.09	0.08	-0.03
ROPSDQ									
ut demand									
RTQ	0.65	1.43	0.55	-3.71	-9.09	-8.67	-1.35	-3.02	-2.78
BORQ	0.60	1.40	1.20	0.90	2.00	2.05	0.52	0.94	0.69

(contd.)

TABLE 8: Scenarios of percentage changes in variables of all mandate crops[1] caused by productivity increase spread over 9 years, 1969-71.

	ALL SAT			WHEAT SAT			RICE SAT		
	1971	1974	1978	1971	1974	1978	1971	1974	1978
Output prices									
JOWARP	-3.18	-8.85	-11.78	-4.71	-11.67	-13.00	-4.79	-11.95	-14.19
OCRSCERP	-1.88	-5.12	-6.98	-2.21	-5.57	-5.87	-2.52	-6.32	-7.66
BGMP					-1.73	-4.61	-4.83		
PULSESP	-3.03	-6.60	-9.30						
GNUTP									
OILSEEDP	-1.11	-3.11	-4.40				-3.34	-7.31	-8.88
Output demand									
RICEQ							-1.17	-2.29	-2.54
WHEATQ				-1.04	-1.14	0.73			
SUPCERQ	-0.23	0.39	-0.35						
OTHCOMSAQ	-1.99	-7.07	-3.46						
OTHCOMSCQ				-1.24	-3.12	-9.70			
OTHCOMSDQ							2.24	1.90	3.18
Expenditure	0.70	2.99	2.91	0.30	2.[illegible]1	[illegible].17	0.20	1.43	1.70

1. Sorghum 25%; other coarse cereals, pulses, and oilseeds, each 10%.
For definition of abbreviated variables, see Appendix Table 1.

than sorghum are not very high[7]. Joint productivity increases however tend to benefit the consumers, and these benefits are substantial in this case.

Conclusions

With the data available and the limited use of modelling for underdeveloped agriculture, we draw the following inferences from our study:

1. Farmers in underdeveloped SAT India do respond significantly to price incentives and modify their production decisions, even for rainfed crops. Similarly, they also revise their consumption basket, depending upon relative prices and real income.

2. Dryland farming being a diversified activity, there are some significant cross-crop responses, particularly between rainfed crops and the dominant high-value crop of the region, implying reallocation of resources based on relative profitability. This requires an integrated supply/demand systems framework for understanding the rainfed crop markets.

3. In view of the simultaneous nature of farmer's production decisions (allocation of resources) and possible lags in supply response, the impacts of exogenous changes led to both allocative and dynamic feedbacks.

4. Since erratic distribution of rainfall with frequent failure of monsoon is a characteristic feature of dryland areas, it is useful to predict the likely impacts of severe droughts–in terms of magnitude, direction, and timing of resource transfers–to facilitate short-run economic planning. The simulation model predicted shifts in resources from moisture-intensive, high-value crops to dry crops in the event of rainfall shortage.

5. Our scenario results tentatively dispel apprehensions regarding likely catastrophic consequences of significant increases in productivity of rainfed crops, particularly sorghum. Moreover, they indicate social benefit to producers as well as consumers, the extent of which differs across cropping zones.

6. There seems to be ample scope for transferring improved sorghum-based cropping systems to wheat-growing areas of Madhya Pradesh and pearl millet-based cropping systems to rice-growing areas of Andhra Pradesh, Karnataka, and Madhya Pradesh. Productivity increases in sorghum have a complementary effect in increasing the production of pulses; pearl millet has a similar effect on oilseeds.

7. These findings are illustrative and conditional upon the chosen demand/supply parameters and simulation methodology. We believe that the magnitude of impacts may change with alternative approaches, but not the directions. Paucity of information precludes any sensitivity analysis for the present. There is an obvious need for more in-depth study and further verification of these results.

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Footnotes

1. BBQ assumed an additive error components structure, with subregional, time, and residual components for the disturbance term in each of the estimating equations. After experimenting with various lag structures for expected price formulation, the following empirical relationship was adopted:

$$\overset{e}{P}_{it} = 0.71\,P_{it-1} + 0.29\,P_{it-2}$$

where P_{it} is the actual price of the ith crop in the period.

2. The simulation model requires three years' data as base information because of the two-year lagged price expectation in its growth rate formulation in supply module. See footnote 1.

3. We used the same supply quantity data for demand series as well for rice, wheat, and superior cereals, owing to non-availability of appropriate data. Hence the MAPE and RMPE values for these variables are misleading.

4. Space limitation precludes inclusion of the graphs here.

5. The exact pattern of assumed annual increases is : 0.5% in 1969, 1.5% in 1970, 3.5% in 1971, 4.5% in 1972, 5.0% in 1973, 4.5% in 1974, 3.5% in 1975, 1.5% in 1976, and 0.5% in 1977. After the ninth year, this leads to a cumulative productivity path 25% above that of base simulation.

6. In order to examine the stability of the model, we duplicated the 1978 data several times and simulated the endogenous values beyond 1978. The simulated path for each endogenous variable became parallel to the base path after a few years, indicating clearly the stability of the model.

7. Experts estimate a two-to-three-fold increase in productivity of rainfed crops as likely potential (Singh, 1983).

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APPENDIX TABLE 1: Definition of variables and their mean, coefficient of variation (CV), and percentage annual growth rates for 1966-1978 by crop zones.

Variable	Abbreviation	Dimension/ units	ALL SAT Mean	ALL SAT CV	ALL SAT % Annual growth rate	WHEAT SAT Mean	WHEAT SAT CV	WHEAT SAT % Annual growth rate	RICE SAT Mean	RICE SAT CV	RICE SAT % Annual growth rate
Quantities											
Rice	RICEQ	1956-57	3501.76	17.50	3.53	515.19	19.64	0.04	4349.33	16.82	3.20
Wheat	WHEATQ	million	1108.56	26.35	5.27	1105.88	26.40	5.29	38.92	27.94	5.30
Sorghum	JOWARQ	Rs	1636.78	8.37	0.48	968.76	10.62	-0.36	674.35	10.61	1.60
Chickpea	BGMQ	"	334.42	17.96	3.50	324.42	18.20	3.50	28.73	18.47	0.31
Groundnut	GNUTQ	"	1010.01	16.27	-1.16	311.28	17.35	-1.83	706.88	18.66	-0.86
Superior cereals	SUPCERQ	"	4628.53	19.07	4.10	1635.46	23.83	4.52	4398.42	16.97	3.30
Other coarse cereals	OCRSCERQ	"	1164.49	19.59	4.20	367.34	21.01	4.70	857.94	18.83	3.70
Pulses	PULSESQ	"	701.15	20.95	4.00	562.91	23.45	3.56	197.21	14.71	0.54
Oilseeds	OILSEEDQ	"	1184.31	15.64	-0.78	402.76	14.80	-0.38	815.22	18.08	-0.01
Other crops Aggr. A	OCROPSAQ	"	1947.98	19.38	4.70	597.73	19.55	4.59	1358.86	21.08	4.77
Other crops Aggr. C	OCROPSCQ	"	7015.63	16.35	3.45	1670.38	17.02	1.95	6794.73	16.81	3.34
Other crops Aggr. D	OCROPSDQ	"	3914.26	19.16	4.40	2341.21	21.44	4.50	1705.85	18.36	4.10
Fertiliser	FERTQ	"	985.31	44.42	11.32	247.34	57.08	14.22	788.92	40.31	9.70
Prices											
Rice	RICEP	Average	2.45	32.45	7.73	2.23	29.93	6.82	2.49	31.96	7.60
Wheat	WHEATP	Price	2.46	26.86	5.41	2.46	26.93	5.40	2.45	25.89	5.30
Sorghum	JOWARP	for	2.55	30.54	6.40	2.61	31.33	6.80	2.46	31.64	5.80
Chickpea	BGMP	1956-57	3.55	37.85	8.31	3.52	38.40	8.50	3.89	35.69	7.59
Groundnut	GNUTP	is equal	3.96	32.29	7.25	3.93	29.78	6.10	3.98	33.84	7.80
Superior cereals	SUPCERP	to one	2.43	30.22	7.10	2.32	26.34	5.64	2.49	31.85	7.55
Other coarse cereals	OCRSCERP	"	2.92	30.04	4.90	2.96	30.85	7.30	2.89	29.68	4.80
Pulses	PULSESP	"	3.87	38.50	9.40	3.82	40.42	9.99	3.97	33.86	7.94
Oilseeds	OILSEEDP	"	3.92	32.18	7.30	3.98	30.59	6.61	3.89	33.29	7.69
Other crops Aggr. A	OCROPSAP	"	3.07	18.72	3.70	2.93	21.50	4.17	3.16	18.54	3.47
Other crops Aggr. C	OCROPSCP	"	2.90	27.52	6.48	3.20	29.05	7.00	2.76	27.85	6.48
Other crops Aggr. D	OCROPSDP	"	3.06	23.54	5.40	3.00	28.52	6.85	3.17	19.26	4.05
Fertiliser	FERTP	"	1.60	34.17	7.50	1.56	33.63	7.50	1.61	34.53	7.60
Labour/wage rate	WAGE	"	3.09	34.27	8.18	3.01	34.43	8.10	3.05	34.35	8.40

(contd.)

(contd.)

APPENDIX TABLE 1: Definition of variables and their mean, coefficient of variation (CV), and percentage annual growth rates for 1966-1978 by crop zones.

Variable	Abbrevi-ation	Dimen-sion/units	ALL SAT Mean	ALL SAT CV	ALL SAT % Annual growth rate	WHEAT SAT Mean	WHEAT SAT CV	WHEAT SAT % Annual growth rate	RICE SAT Mean	RICE SAT CV	RICE SAT % Annual growth rate
Other variables											
Rainfall	RAIN	mm	899.62	11.51	1.20	937.15	14.09	0.51	955.19	10.02	1.23
H.Y. varieties	HYK	% of GCA	8.12	67.51	17.14	5.73	74.03	18.75	10.75	65.76	16.55
Roads	ROADL	Km/10 km^2	2.21	19.26	4.76	1.70	17.34	4.43	2.38	20.92	5.03
Markets	MKTS	No./10,000km^2	8.91	25.43	6.59	8.67	12.13	3.05	7.81	38.69	9.81
Irrigation	IRK	% of GCA	16.81	9.59	2.35	7.96	22.24	5.57	23.48	5.70	1.26
Expenditure		Million Rs.	29037.50	35.98	9.1	11783.40	35.61	9.1	20780.60	35.77	9.03

GCA: Gross cropped area; LABORQ: Labour Quantity; EDBOILSQ, P: Edible Oils Quantity, Price; OTHCOMS AQ, CQ, DQ: Other Commodit aggregates A,C,D.

FIFTEEN

SUMMARY OF PROCEEDINGS POLICY FOR DRYLAND AGRICULTURE : POTENTIAL AND CHALLENGE*

N.S. Jodha**

Background

Following the green revolution in the well-endowed areas of India in the late 1960s, the widening gap between dry and wet regions became a matter of serious concern. Several public interventions followed. Increased investment in agricultural research in dry-farming areas since the early 1970s was a major intervention. By the early 1980s a scenario developed where scientists (off and on the record) claimed to have generated improved technologies for dry-farming regions, bankers reported their unending search for fundable technologies, and farmers continued to complain about non-availability of relevant technologies. Each could be right in their own way, but the whole debate has generated an atmosphere of hope mixed with despair. It was in that context, to have a clearer understanding of the situation, that the Indian Society of Agricultural Economics (ISAE)–in association with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the All India Coordinated Research Project for Dryland Agriculture (AICRPDA)–

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