SEMINAR SERIES – XI

Seminar on

DEMAND AND SUPPLY PROJECTIONS FOR AGRICULTURAL COMMODITIES

THE INDIAN SOCIETY OF AGRICULTURAL
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PREDICTING CROP PRODUCTION IN HARYANA (APPLICATION OF RECURSIVE PROGRAMMING TECHNIQUE)

Daya Singh and A. S. Kahlon*

INTRODUCTION

The major problems of agriculture revolve round supply functions and relationships of product output with factor inputs. These provide a framework for adjusting production and resource employment to promote general economic development. This is specially true in India where planning has been accepted as a tool of economic development and perspective planning as a technique. Indian Government's policy about procurement, distribution, imports and support prices of most agricultural products, is largely determined by advance estimates of crop production. Improved knowledge of the potential future supply structure is needed under rapidly changing technology and factor-product prices. This information is useful for appraisal of problems and potentialities in inter-regional competition and area development.

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Indian agricultural policy in the past was formulated on the implicit assumption of certain supply relationships which did not have an adequate base. Thus, the production imbalance in Indian agriculture continues to underscore the need for policy-oriented research. Hence empirical and factual knowledge of supply relations of agricultural commodities is needed to identify possible maladjustments and to formulate a sound agricultural policy.

Empirical prediction of agricultural supply is a difficult task, not because there are millions of farmers on whose decisions and actions production depends, but more so due to risk and uncertainty involved in agriculture. Further, the complex structure of agriculture involving the impact of technology, structural changes, investment in fixed or quasi-fixed factors, aggregation and non-availability of appropriate statistical data, limit the precision of supply predicting techniques. To solve this problem, recursive programming technique was used because of its direct relation to the theory of production.

METHODOLOGY

An empirical study was made in Haryana to examine the suitability of recursive programming as one of the tools of predictive analysis. A recursive programming (R.P.) model at State level was set up separately for each year, treating each production year as a different decision-making process for the farmers. Three different tests, namely, explanatory test (1961-62 to 1965-66), predictive test (1966-67 to 1967-68) and projection test (1968-69 to 1973-74) were made in this analysis of supply response, using both recursive programming and regression models.

Explanatory test (1961-62 to 1965-66): This test explained how *ex-post* changes occurred in the past. It was considered appropriate to use the data for the entire past period to explain the results in a particular year of this period.

Predictive test (1966-67 to 1967-68): This test used no advance information except what was known *ex-ante* each year. Recursive programming and regression predictions were based only on the preceding year information. This test was more rigorous than the explanatory test and more nearly represented the situation in which the real problems of prediction were confronted by the farmers.

Projection test (1968-69 to 1973-74) : The term projection was used instead of 'long run prediction,' because in projection, certain set of data were presumed rather than predicted. This involved making a series of forecasts recursively year by year through 1973-74.

BASIC DATA

Selection of Alternative Activities

Haryana farmers were engaged in numerous agricultural enterprises. However, in this study we limited the number of basic land use alternatives to important annual crops such as wheat, gram, rape and mustard, bajra, maize, paddy, sugarcane, American cotton and *desi* cotton which covered about 79 per cent of the cropped area of the State. Alternate production techniques of these crops and of the recently introduced Mexican wheats, hybrid bajra and high-yielding rice were defined in each year on the basis of irrigation facilities and the level of production technology. The use of modern inputs was largely based on the availability of irrigational facilities. Thus the activities defined on irrigated land in _kharif_ and _rabi_ season were further stratified according to the level of agricultural inputs used.

(i) Irrigated activity with full adoption of improved practices.

(ii) Irrigated activity with moderate adoption of improved practices.

(iii) Irrigated activity with low adoption of improved practices.

(iv) Irrigated activity with no use of inorganic fertilizers and plant protection measures and poor adoption of other improved practices.

Similar break-up of different input levels of unirrigated enterprises was not required because in the absence of irrigational facilities, the adoption level of modern inputs would not change much. Specification of activities on this pattern seemed to be more appropriate for supply projections under changing conditions of recent break-through in agriculture of the operational study area. In this way, 61 activities were defined for individual years in the explanatory period and 74 activities in the predictive and projection period.

Expected yield: The yield projections for 1968-69 and onwards were made on the basis of three years moving average, starting from 1965-66. The expected yields of irrigated activities were made on the basis of production yardsticks. In yardstick approach, the yield estimates of an activity at given level of inputs remained constant over time, but overall average yield for a particular year would change with the change in the adoption level of modern inputs.

Expected cost: Variable costs per hectare were calculated for different activities. The level of agricultural inputs for each defined activity was estimated first in physical terms (per hectare hired man hours, kgs. of fertilizers, cart loads of farmyard manure, amount of pesticides, seed rate, irrigation level, etc.) and these quantities were multiplied by the expected unit cost to get the variable cost per hectare. The expected unit cost in the projection period was assumed to increase on the past pattern.

Expected price: For regression analysis, six price expectation models were formulated to represent farmers' product price expectations. The expected normal price of regression equation giving the best fit was considered as expected price of the produce in recursive programming model. The moving average price of recent three years of of the best fitted price model represented the expected price of the product in the projection period.

Expected net returns: Finally, the net returns over variable costs of each activity were calculated using the following formula:

$$R_{it} = (P_{it} \times Y_{it}) - C_{it}$$

where R_{it} = expected net returns of the activity in year t,

P_{it} = expected price of the product of ith activity in year t,

Y_{it} = expected yield per hectare of ith activity in year t,

C_{it} = expected variable cost per hectare of ith activity in year t.

Estimation of constraints: An effort was made to quantify all such major restrictions which actually affected the cropping pattern and production of crops throughout the test period. However, the non-availability of basic data was a serious limitation. The following constraints were included in the present study:

Total land: For estimating total cropped land constraint, it was assumed that actual area under nine crops of the study would approximate the supply of total land suited to these crops. This assumption seemed to be valid as the crop activity was usually more profitable than leaving the land idle. Thus total cropped area constraint in the explanatory period (1961-62 to 1965-66) was set equal to total crop area under nine crops included in the study. For predictive and projection periods, it was assumed to be equal to the regression area estimates for these crops.

Land of different types: Stratification of land based on its physical properties was desirable according to the procedures drawn by Day[1], and Schaller[2] in their studies on the acreage change in Mississippi and California respectively. In their studies, they sub-grouped the regions into several areas according to the physical characteristics of soils. The assumption of additivity could be fulfilled only under the condition that each resource was considered to be homogeneous. However, due to the lack of availability of this kind of data, we were compelled to use State level data. Nevertheless total cropped land was divided into four land types, namely, *kharif* irrigated land, *kharif* unirrigated land, *rabi* irrigated land and *rabi* unirrigated land based on the available distribution pattern. For predictive period and projection period, the area under *kharif* and *rabi* crops was assumed to increase on the basis of past trend. The remainder of the projected area was unirrigated area.

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1. Richard H.Day: Recursive Programming and Production Response, North Holland Publishing Co., Amsterdam, 1963.
2. William Neil Schaller: A Recursive Programming Analysis of ·ional Production Response, Ph.D. Thesis, University of California, 1962.

Irrigation capacity constraints: The estimation of water constraint was based on the assumption that demand for water in peak period was in close approximation to the actual supply of water. This assumption was quite logical for Haryana, where irrigation was perhaps one of the most scarce resource. The growing season was divided into two critical time periods and the supply of water in each period was treated as a different input.

Period	Months
1	March-June
2	October-December

In the explanatory period, the irrigation constraint of these two periods was set equal to the actual irrigation capacity. Water constraint for predictive period and projection period was estimated through the least squares equation $Z_t = (1 + B) Z_{t-1}$ where Z_t and Z_{t-1} were the irrigation capacities in hectares in period t and t-1 respectively. B indicated the rate of increase in irrigation capacities. The irrigation capacity constraints so estimated were compared with the irrigation targets fixed for the Fourth Five-Year Plan and were found to be in good agreement.

Constraints on fertilizers: Total fertilizer distributed in Haryana was divided in the ratio of irrigated area under the major crops included in the study to the irrigated area under the excluded crops. The irrigated area under the relevant crops was approximately 80 per cent every year from 1961-62 through 1967-68. Thus 80 per cent of the fertilizers were assumed to be allocated to the crops under study. These quantities of nitrogenous and phosphatic fertilizers were considered as fertilizer constraints during the explanatory period. For the predictive period, fertilizer constraints in terms of nitrogen and phosphorus were estimated by the equation $F_t = (1 . B) F_{t-1}$. The constraints for the projection period were set equal to 80 per cent realization of fertilizer distribution targets of the Fourth Five-Year Plan.

Constraints on improved seeds: Total available improved seeds of hybrid bajra, Mexican wheats and high-yielding rice varieties were included in predictive and projection period recursive programming matrices as constraints. Total improved seed constraints for the predictive period were set equal to the actual seed distribution of these varieties. For projection period the targets of the Fourth Five-Year Plan were assumed to be realized.

Flexibility constraints: Farmers' decision-making process regarding allocation of land to different crops is influenced by a large number of factors, some of which are measurable at least in principle, while others cannot be measured directly. These are indirectly taken into account through flexibility constraints in a programming model. These flexibility limits may be defined in several ways. Here the average of absolute difference between the actual area and the estimated area $(X_t - \hat{X}_t)$ from the best fitted regression model was used for the explanatory period of the present study. The average of positive deviations was taken as the upper bound and of negative deviations as the lower bound on the conditional point estimate forecast by regression analysis. Proportionate upper and lower bounds on irrigated area of the relevant crop were specified accordingly. Flexibility constraints specified in this way made greater use of regression estimates which could be improved further through recursive programming. In the predictive period, the maximum of these absolute deviations were placed as upper and lower bounds on the recursive programming solutions of irrigated area and total area under the relevant crop in the preceding year. In the projection period, proportionate changes were computed for each crop by the formula:

$$B_j = \sum_{j-1}^{a} \frac{X_{j(t)} - \hat{X}_{j(t)}}{\hat{X}_{j\,t}} \Big/ n.$$

Where $X_{j(t)}$ was the crop area of jth crop in year t; $\hat{X}_{j(t)}$ was the area solution of recursive programming model for jth crop in year t, and n was the number of observations from 1961-62 through 1967-68. Thus flexibility coefficient expressing constant percentage increase or decrease, was placed on recursive programming model area solution in year 't' to represent approximate limits for year 't + 1'. Similar method was followed for specifying the coefficient on irrigated area of the crop included in the present study.

The real activities ranging from 61 to 74 and their input-output coefficients along with 45 to 48 constraints spelt out in this manner were used to set up a recursive programming matrix. Simplex method was used for obtaining solution of recursive programming problem, treating maximum restrictions as disposal activities and minimum restrictions as artificial activities. The results obtained are presented for comparison with the actual values and the solutions of regression model.

Regression Approach

Two single equation linear models of Nerlovian type were also fitted individually to each crop.

$$X_{it} = a_o + a_1 X_{it-1} + a_2 P_{ijt-1} + a_3 W_{ikt} + e_{it}$$

$$X_{it} = a_o + a_1 Y_{it-1} + a_2 R_{ijt-1} + a_3 W_{ikt} + e_{it}$$

X_{it} and X_{it-1} = Irrigated + unirrigated area of ith crop in thousand hectares in Haryana in year t and year t-1 respectively.

P_{ijt-1} = The expected normal price of jth model of ith crop relative to alternative crops.

R_{ijt-1} = The expected per hectare normal gross returns of jth model of ith crop relative to alternative crops.

W_{ikt} = Average value of kth weather factor of three pre-sowing months of ith crop for year t.

e_{it} = An error term for the ith relationship.

i = 1, 2, ... 9 crops

j = 1, 2, ... 6 price expectation models

k = 1, 2 weather models.

The nine crops were wheat, gram, rape and mustard, bajra, maize, paddy, sugarcane, American cotton and desi cotton. The six price expectation models used were:

$P_{t-1(1)}$ = Average price realised by farmers during three pre-sowing months.

$P_{t-1(2)}$ = Average price realised by farmers during three post-harvest months.

$P_{t-1(3)}$ = Average price realised by farmers during three pre-sowing months and three post-harvest months.

$P_{t-1(4)}$ = Average price realised by farmers during 12 post-harvest months.

$P_{t-1(5)}$ = Model price realised by farmers during 12 post-harvest months.

$P_{t-1(6)}$ = Linear trend price.

Similarly, six gross returns expectation models were formulated. Two weather models used alternatively in the estimating equation were:

$W_{t(1)}$ = The average weather index of three pre-sowing months of the concerned crop. Weather index was of the form $W = P/T$, where W indicated weather index, P indicated average precipitation of three pre-sowing months in mm. and T indicated the average temperature of three pre-sowing months in centigrade.

$W_{t(2)}$ = The average rainfall in mm. of three pre-sowing months of the relevant crop.

In order to obtain the estimation of crop production from regression analysis, the area estimates (in thousand hectares) from the best fit equation (highest R^2 value) estimated for an individual crop was multiplied by expected yield per acre. The expected yield was represented by three-year average of lagged actual yields per hectare of three preceding years. The output obtained was as under:

$$O'_{it} = \frac{(Y_{it-1} + Y_{it-2} + Y_{it-3})}{3} X_{it}$$

Where O'_{it} was the predicted output of ith crop in year t, Y_{it} was the actual yield per hectare of ith crop in year t and X_{it} was the area predicted in hectares of ith crop from the most acceptable equation.

RESULTS

Explanatory Test (1961-62 to 1965-66)

The post-changes occurring in the test period were great enough to provide a challenging test to the explanatory ability of the alternative models. The data of the entire period (1952-53— 1965-66) were used to explain the area and output in a particular year. For example, Nerlovian regression equations were fitted to the data from 1952-53 through 1965-66. Likewise, recursive programming model used advance information in this period to estimate flexibility constraints, etc. The area and output of this test are shown in Tables I and II. The percentage deviation of the explained from the actual area and production for recursive programming and best fitted regression models for each crop during the test period are summarized in Tables III and IV. The regression results of best fitted equations for different crops are presented in Table V.

The results of explanatory test showed that the average errors in the area estimates of recursive programming model were lower than the regression errors for all crops except <u>desi</u> cotton.

The year by year comparison provided the lower average crop error in recursive programming model in all years but one.

Table I - Estimated and Actual Area of Major Crops in Haryana: An Explanatory Test (1961-62 —— 1965-66)

(area in thousand hectares)

Year	Wheat			Gram			Rape and mustard		
	Actual	Regression	R.P.	Actual	Regression	R.P.	Actual	Regression	R.P.
1	2	3	4	5	6	7	8	9	10
1961-62	648	636	652	1595	1470	1404	196	161	109
1962-63	670	659	685	1443	1389	1420	252	221	250
1963-64	689	670	674	1418	1430	1367	224	260	268
1964-65	723	718	731	1319	1406	1320	154	178	154
1965-66	678	715	718	888	1270	1150	153	154	160

Year	Bajra			Maize			Paddy		
	Actual	Regression	R.P.	Actual	Regression	R.P.	Actual	Regression	R.P.
1	11	12	13	14	15	16	17	18	19
1961-62	773	794	771	88	98	88	163	170	174
1962-63	713	755	700	111	89	106	165	177	180
1963-64	677	688	664	116	116	106	158	175	177
1964-65	791	739	759	93	107	113	185	184	187
1965-66	780	763	762	88	94	98	192	212	193

(contd.)

Table I (concld.)

Year	Sugarcane			American cotton			Desi cotton		
	Actual	Regression	R.P.	Actual	Regression	R.P.	Actual	Regression	R.P.
1	20	21	22	23	24	25	26	27	28
1961-62	137	129	137	50	54	49	68	51	45
1962-63	129	132	139	56	61	58	62	56	63
1963-64	114	131	136	100	95	99	77	78	83
1964-65	144	137	145	101	108	109	74	70	76
1965-66	181	189	185	113	111	114	83	87	92

Table II - Estimated and Actual Production of Major Crops in Haryana: An Explanatory Test (1961-62—1965-66)

(production in thousand tons)

Year	Wheat			Gram			Rape and mustard		
	Actual	Regression	R.P.	Actual	Regression	R.P.	Actual	Regression	R.P.
1	2	3	4	5	6	7	8	9	10
1961-62	870	798	752	985	1196	981	111.4	94.8	108.4
1962-63	804	865	746	905	1041	929	148.3	130.2	139.0
1963-64	834	856	830	966	1021	924	136.8	147.3	146.7
1964-65	922	898	906	968	793	739	76.9	104.8	75.7
1965-66	869	878	890	385	529	672	74.9	87.2	80.1

(contd.)

Table II (concld.)

Year	Bajra			Maize			Paddy		
	Actual	Regres-	R.P.	Actual	Regression	R.P.	Actual	Regression	R.P.
1	11	12	13	14	15	16	17	18	19
1961-62	262	234	270	83	87	83	203	268	200
1962-63	262	241	241	71	87	89	154	253	201
1963-64	250	230	242	129	94	89	220	193	195
1964-65	287	265	276	92	96	105	266	219	216
1965-66	208	280	271	106	86	90	204	260	227

Year	Sugarcane			American cotton			*Desi* cotton		
	Actual	Regression	R.P.	Actual	Regression	R.P.	Actual	Regression	R.P.
1	20	21	22	23	24	25	26	27	28
1961-62	439	495	398	13.52	12.79	14.00	11.96	11.70	9.34
1962-63	451	480	368	14.11	15.60	16.44	18.04	15.13	12.65
1963-64	515	467	363	31.87	24.70	28.32	21.68	20.38	18.32
1964-65	678	512	575	31.54	30.24	30.22	20.00	16.06	18.20
1965-66	717	802	720	30.59	32.64	32.60	21.88	20.57	24.45

Table III - Percentage Deviation of 'Explained' from 'Actual' Area of Major Crops in Haryana: An Explanatory Test (1961-62—1965-66)

Year	Wheat		Gram		Rape and mustard		Bajra		Maize	
	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.
1	2	3	4	5	6	7	8	9	10	11
1961-62	-1.85	+0.62	+5.68	+0.65	-17.86	-4.08	+2.72	-0.26	+11.36	0.00
1962-63	-1.61	+2.24	-3.74	-1.59	-12.30	-0.79	+5.89	-1.82	-19.82	-4.50
1963-64	2.76	-2.18	+0.85	-3.60	+11.61	+19.64	+1.63	-1.92	0.00	-8.62
1964-65	-0.60	+1.11	+6.60	+0.08	+15.58	0.00	-6.57	-4.05	+15.05	+21.50
1965-66	+5.46	+5.63	+46.31	+32.40	+0.65	+4.57	-2.18	-2.31	+6.82	+11.36
Average	2.48	2.36	12.58	7.68	11.60	7.11	3.80	2.07	10.61	9.20

Year	Paddy		Sugarcane		American cotton		Desi cotton	
	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.
1	12	13	14	15	16	17	18	19
1961-62	+4.29	+6.75	-5.84	0.00	+8.00	-2.00	-12.07	-22.4
1962-63	+7.27	+9.09	+2.33	+7.57	+8.93	+3.57	-9.68	+1.61
1963-64	+10.76	+12.02	-14.91	-19.29	-5.00	-1.00	-1.30	-7.79
1964-65	-0.54	+1.08	-4.86	+0.69	+6.93	+7.92	-5.41	+2.70
1965-66	+10.42	+0.52	+4.42	+2.20	-1.77	+0.88	+4.82	-1.20
Average	6.66	5.89	6.45	5.95	6.13	3.08	6.66	7.14

Table IV - Percentage Deviation of 'Explained' from 'Actual' Production of Major Crops in Haryana: An Explanatory Test (1961-62— 1965-66)

Year	Wheat		Gram		Rape and mustard		Bajra		Maize	
	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.
1	2	3	4	5	6	7	8	9	10	11
1961-62	-8.28	-13.56	+21.42	-0.41	-14.90	-2.69	-10.69	+3.05	+4.82	0.00
1962-63	+7.59	-7.21	+15.03	+2.65	12.20	-6.27	-8.37	-8.36	+22.54	+25.35
1963-64	+2.64	-0.48	+53.30	+23.72	+7.68	+7.23	-8.00	-3.20	-27.13	-31.00
1964-65	-2.61	+1.74	+18.08	-23.66	+29.90	-1.56	-7.67	-3.83	+4.35	+14.13
1965-66	+1.04	+2.72	+37.40	+74.54	+12.30	6.94	+34.62	+30.28	-18.87	-15.09
Average	4.43	5.08	29.05	24.99	17.50	4.54	13.87	9.54	15.54	17.12

Year	Paddy		Sugarcane		American cotton		Desi cotton	
	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.
1	12	13	14	15	16	17	18	19
1961-62	31.03	-1.47	+12.76	-9.33	-5.40	+2.55	-2.17	-21.91
1962-63	+64.28	+17.53	+ 6.43	-18.40	+11.20	+16.51	-29.88	-16.13
1963-64	-12.27	-11.36	-9.32	-29.51	-22.50	-11.13	-15.50	-5.99
1964-65	-17.67	-15.04	-24.48	-14.75	-4.12	-4.18	-9.00	-4.70
1965-66	-30.39	-11.27	+11.88	+1.67	+6.70	+6.57	-11.75	+18.88
Average	31.30	11.34	12.97	14.73	9.98	8.39	17.61	9.58

Table V - Regression Equations Used for Explanatory Test (1961-62—1965-66)

Crop	Equation	R^2
Wheat	$X_t = -83.1209 + .8830X^{**}_{t-1} + .4430W_{t(2)} + .3106R^{*}_{t-1(4)}$	.9649
	(.0570) (.1190) (.1228)	
Gram	$X_t = -277.6033 + .5478X^{**}_{t-1} + 2.6809W_{t(2)} + 16.4841P^{*}_{t-1(4)}$	.9103
	(.0897) (1.0779) (5.2873)	
Rape and mustard	$X_t = 30.2642 + .2158X^{**}_{t-1} + .5864W_{t(2)} + .6392P^{*}_{t-1(3)}$	.6982
	(.1592) (.2018) (.2597)	
Bajra ..	$X_t = 215.4478 + .4814X^{**}_{t-1} + 9.5970W^{**}_{t(2)} + 2.8920P^{*}_{t-1(2)}$	.9203
	(.924) (2.006) (1.2380)	
Maize ..	$X_t = -31.4299 + .7625X^{**}_{t-1} + 29.377W_{t(1)} + .147R^{**}_{t-1(3)}$	.8628
	(.1331) (30.070) (0.065)	
Paddy ..	$X_t = -21.4237 + .9994X^{**}_{t-1} + 1.379W_{t(2)} + .6638P_{t-1(6)}$	.9691
	(.0632) (.8578) (.4616)	
Sugarcane ..	$X_t = -36.6099 + .9087X^{**}_{t-1} + 8.237W_{t(1)} + 1.035P^{**}_{t-1(3)}$	.9447
	(.1015) (4.849) (.227)	
American cotton	$X_t = -30.887 + .733X^{**}_{t-1} + .639W_{t(2)} + .229P_{t-1(4)}$	.7650
	(.166) (.623) (.147)	
<u>Desi</u> cotton	$X_t = -83.9188 + 21.4953W^{*}_{t(1)} + 1.5761P^{*}_{t-1(3)}$	.8295
	(10.4222) (0.3086)	
	$X^d_t - 18.5387 + .4112X^{**}_{t-1}$	.4250
	(.1380)	

Note: Each equation was selected on the basis of the highest R^2 from different alternative equations using data 1952-58 through 1965-66. Gram and desi cotton were the exception. Gram equation was estimated after dropping 1965-66 which was an abnormal year. In case of desi cotton residual analysis was done due to multicollinearity problem. Numbers in parentheses are standard errors.

* Significant at 5 per cent level of significance.

** Significant at 1 per cent level of significance.

The production estimates were less accurate than estimates of area in all the years and for all crops. This was expected because error of the yield estimate was compounded with the error in estimated acreages in the estimated total production. The comparison of production results of the two models indicated that regression errors for only three crops out of nine were slightly less than the recursive programming errors. The average crop production error was considerably higher for regression models throughout the test period. Thus the simultaneous explanation of area and production by recursive programming model provided somewhat better results of output.

The errors of area estimation for a crop, which had small acreage with greater fluctuation, were usually larger than those for a crop which had large area and a relatively stable area path. The errors in the production estimates of those crops tended to be larger where the percentage of unirrigated area was higher. It was noted that recursive programming model had a tendency to over-estimate the area of more profitable crops.

Some information about why certain changes occurred could be known by careful estimation of the basic production relationships, interaction of competitive crops and constraint in general and flexibility constraints in particular of recursive programming model.

If all the upper and lower bounds were always effective, the upper bound would always be reached for the most profitable crops and lower bound attained for the least profitable. Table VI shows the effective bounds in the explanatory period.

It was apparent from Table VI that the area under wheat, gram and rape and mustard moved in close association. Gram was the least profitable crop as indicated by the lower bounds and its area was adjusted corresponding to the change in the area of wheat and rape and mustard. Gram area was somewhere between the two bounds in 1961-62 and 1962-63 when both wheat and rape and mustard

Table VI - Effective Area Bounds in Haryana Recursive Programming Model: An Explanatory Test (1961-62—1965-66)

Crop	1961-62	1962-63	1963-64	1964-65	1965-66
Wheat ..	U	U	—	U	U
Gram ..	—	—	L	—	L
Rape and mustard	U	U	U	L	—
Bajra ..	L	L	L	—	—
Paddy ..	U	U	U	U	—
Maize ..	L	U	L	U	U
Sugarcane ..	U	U	—	U	—
American cotton	L	—	U	—	U
Desi cotton ..	L	U	—	U	L

U denotes upper bound effective
L denotes lower bound effective

reached their upper bounds. In 1963-64, gram area declined to the lower bound, rape and mustard attained the upper bound, and wheat area was somewhat between the two bounds. Wheat area increased to the upper bound in 1964-65, rape and mustard area declined to the lower bound, and the gram area lay between the two limits. Again, in 1965-66 gram area declined to the lower bound, wheat area attained the upper bound, and the rape and mustard area was somewhere between the upper and lower limits. Similarly, substitution relationships were apparent in sugarcane, American cotton and *desi* cotton. In 1962-63, sugarcane reached the upper bound causing cotton to decline to lower limits. Sugarcane and *desi* cotton attained the upper bounds in 1962-63 and 1964-65 and American cotton adjusted somewhere between the two bounds. In 1963-64 and 1965-66, the area of American cotton increased to the upper bound and the areas of sugarcane were adjusted between the two bounds in 1963-64 and fell to the lower bound in 1965-66. The solutions provided by the recursive programming model were more than a set of bounds on each crop. However more than two-thirds of these estimates were constrained by the crop's own upper and lower flexibility constraints. If the model could more fully specify relevant constraints, it would impose less burden on flexibility constraints and give better results.

Predictive Test (1966-67— 1967-68)

This test used no advance information and the analysis was based entirely on the data of the preceding year. In a sense the results could be regarded as one year forecasts. The regression estimates of crop area of major crops in 1966-67 were predicted from the regression equations with the best fit which used data for 1952-53 through 1965-66. The results of these equations are given in Table V. To predict the area for 1967-68, these equations with the best fit were refitted to data through 1966-67 and are presented in Table VII. Recursive programming solutions for each of the subsequent years were based on the solutions of the preceding year rather than on regression point estimates. The results of this test are presented in Tables VIII and IX. The percentage deviation of predicted area and production from actual values is given in Table X and XI respectively.

It was apparent from the results that predictive models gave large errors of the estimates than the explanatory models. Overall position regarding area of the nine crops estimated by models in this test period showed that the errors in the predicted area increased from 7.36 per cent to 17.66 per cent in regression model and from 5.66 per cent to 10.16 per cent in recursive programming estimates. Likewise, there was an increase in errors of the production estimates.

Again, recursive programming maintained its superiority by predicting area and production of relevant crops more accurately. The average error in this test period both in area and production

Table VII - Results of Regression Equations Used in Predictive Test (1966-67 — 1967-68)

Crop		Equation	R^2
Wheat	..	$X_t = -93.7281 + 8863X^{**}_{t-1} + .4361W^{*}_{t(2)} + .3421R^{**}_{t-1(4)}$ (.0572) (.2137) (.1123)	.9689
Gram	..	$X_t = -363.1289 + .5410X^{**}_{t-1} + 2.6142W^{*}_{t(2)} + 18.9242P^{*}_{t-1(4)}$ (.1064) (1.4403) (7.0606)	.8538
Bajra	..	$X_t = 197.2831 + .5409X^{**}_{t-1} + 4.2901W^{**}_{t(2)} + 3.7374P_{t-1(2)}$ (.1163) (1.2726) (2.0056)	.8579
Maize	..	$X_t = -3.3771 + .7035X^{**}_{t-1} + 1.1240W_{t(1)} + .1092R_{t-1(3)}$ (.1154) (10.1666) (.534)	.8591
Paddy	..	$X_t = -0.3733 + .9785X^{**}_{t-1} - 0.0181W_{t(2)} + .4895P_{t-1(5)}$ (.0771) (.8189) (.3615)	.9589
Sugarcane	..	$X_t = -21.1691 + .7072X^{**}_{t-1} + 9.8411W_{t(1)} + 1.0692P^{*}_{t-1(3)}$ (.1145) (6.7299) (.3164)	.9025
American cotton	..	$X_t = -16.6033 + .5629X^{**}_{t-1} - 1050W_{t(2)} + .3116P^{*}_{t-1(4)}$ (.1564) (.4988) (.1588)	.7056
Rape and mustard	..	$X_t = 3.1582 + .2469X_{t-1} + .5994W^{**}_{t(2)} + .6298P^{*}_{t-1(3)}$ (.1717) (.1884) (.2751)	.7050
<u>Desi</u> cotton	..	$X_t = -104.1807 + 33.2525W_{t(1)} + 1.7842P_{t-1(3)}$ (9.2693) (.3237)	.8628
		$X^d_t = 18.1745 + .3540X^{*}_{t-1}$ (.1253)	.6780

Note: Data used 1952-53 through 1966-67 for all crops except gram (omitting 1965-66 due to abnormal year). Numbers in parentheses are standard errors.

* Significant at 5 per cent level of significance.

** Significant at 1 per cent level of significance.

Table VIII - Estimated and Actual Area of Major Crops in Haryana: A Predictive Test (1966-67— 1967-68)

(area in thousand hectares)

Crop	1966-67			1967-68			1968-69		
	Actual	Regression	R.P.	Actual	Regression	R.P.	Actual	Regression	R.P.
1	2	3	4	5	6	7	8	9	10
1. Wheat	743	720	758	841	810	798	895	843	832
2. Gram	1,062	1,287	1,032	1,160	1,272	1,163	562	1,170	1,094
3. Rape and mustard	198	207	193	233	233	237	-	194	227
4. Bajra	893	1018	806	885	835	844	872	794	813
5. Maize	87	122	102	115	95	107	99	113	105
6. Paddy	192	232	204	217	212	216	233	237	205
7. Sugarcane	150	191	185	121	145	166	161	135	183
8. American cotton	81	123	115	138	93	136	-	131	125
9. Desi cotton	102	98	95	103	92	106	-	90	99

Table IX - Estimated and Actual Production of Major Crops in Haryana: A Predictive Test

(production in thousand tons)

Crop	1966-67			1967-68			1968-69		
	Actual	Regression	R.P.	Actual	Regression	R.P.	Actual	Regression	R.P.
1. Wheat	1,059	904	899	1,425	1,075	1,269	1,522	1,241	1,248
2. Gram	531	583	485	1,267	647	654	411	794	843
3. Rape and mustard	80.1	111.8	87.4	95.0	109.7	118.5	-	92.2	133.2
4. Bajra	373	339	265	459	221	348	459	318	414
5. Maize	86	134	104	125	101	110	73	123	110
6. Paddy	223	301	184	287	259	239	265	280	211
7. Sugarcane	510	840	569	471	583	429	673	507	676
8. American cotton	24.2	36.9	28.1	39.2	27.3	51.9	-	37.34	23.25
9. Desi cotton	27.6	29.4	26.7	28.1	32.1	25.2	-	24.84	44.27

Table X - Percentage Deviation of 'Predicted' from 'Actual' Area of Major Crops in Haryana: A Predictive Test (1966-67—1967-68).

Crop	1966-67		1967-68		1968-69		Average of			
							Two years		Three years	
	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.
1. Wheat	-3.10	+2.02	-3.69	-5.11	-5.81	-7.05	3.40	3.57	4.20	4.73
2. Gram	+21.19	-2.82	+9.66	+0.26	+108.19	+94.56	15.43	1.54	46.35	32.58
3. Rape and mustard	+4.55	-2.52	0.00	+1.72	-	-	2.28	2.12	-	-
4. Bajra	+14.00	-10.41	-5.65	-4.63	-8.94	-6.76	9.83	7.52	9.53	7.27
5. Maize	+40.23	+17.24	-17.39	-6.96	+14.14	+6.06	28.81	12.10	23.92	10.09
6. Paddy	+20.83	+6.25	-2.30	-0.46	+1.72	-12.02	11.57	3.36	8.28	6.24
7. Sugarcane	+27.33	+23.33	+19.83	+37.19	-16.15	+13.66	23.38	30.26	20.97	24.73
8. American cotton	+51.85	+41.97	-32.61	-1.45	-	-	42.23	21.71	-	-
9. Desi cotton	-8.91	-4.95	-10.68	+2.91	-	-	9.80	3.93	-	-

Table XI - Percentage Deviation of 'Predicted' from 'Actual' Area of Major Crops in Haryana: A Predictive Test (1966-67—1967-68)

Crop	1966-67		1967-68		1968-69		Average of Two years		Average of Three years	
	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.
1. Wheat	-14.64	+15.11	-24.56	-9.54	-18.46	18.00	19.60	12.33	19.22	14.22
2. Gram	+9.79	-8.66	-48.93	-48.38	+93.19	+105.11	29.36	28.52	50.64	54.05
3. Rape and mustard	+39.70	-9.11	+15.47	+24.73	-	-	27.59	16.92	-	-
4. Bajra	+9.12	-28.95	-36.60	-24.18	-30.72	-9.80	22.86	26.57	25.48	20.48
5. Maize	+55.81	+23.25	-19.20	-12.00	+68.49	+50.68	37.51	17.63	47.83	28.64
6. Paddy	+64.71	+11.56	+23.78	-8.92	-24.96	+0.45	44.25	10.24	37.82	6.98
7. Sugarcane	+34.98	+17.48	-9.76	-16.72	-	-	41.40	24.29	-	-
8. American cotton	+52.61	+16.17	-30.36	+32.40	-	-	41.40	24.29	-	-
9. Desi cotton	-3.37	-10.29	-14.23	-10.32	-	-	8.80	10.30	-	-

estimates was lower in the recursive programming model than in the regression model for seven of the nine crops estimated by both the models.

Moreover, each regression estimate was independent of the errors in the estimates of other crops while the production of different crops was inter-dependent. Thus, the results obtained by regression model might not be as dependable as that of recursive programming model even when the regression coefficients were significant.

Projection Test (1968-69—1973-74)

Short run forecasts were inadequate to provide solutions for certain policy problems. Long run supply projection could suggest readjustment required in certain agricultural programmes. For that purpose, six years projections were extended covering the Fourth-Five-Year Plan period. This test involved making a series of forecasts recursively year by year from 1968-69 through 1973-74 for both the recursive programming and regression models. Of course, it could not be called a test in the strict sense of the term because solutions could not be compared with actual data which were not available for these years.

Based on regression analysis, year by year projections were made upto 1973-74. The equation with the best fit, using data through 1965-66, was again fitted to the data through 1967-68 and was used as the basic equation for supply projection. The results are shown in Table XII. Expected relative price and pre-sowing weather variables were empirically estimated for 1968-69. For further period the expected relative price (or gross returns) were assumed to be based on recent trends, that is, the average changes in these values in the most recent three years. These values were projected as the moving average of the most recent three years. Similarly, the values of weather variables from 1968-69 onwards were projected as the average of the most recent five years to represent

Table XII - Results of Regression Equations Used in Projection Test

Crop	Equation	R^2
1. Wheat	$X_t = -114.0817 + .8930X^{**}_{t-1} + .4465W^{*}_{t(2)} + .3858R^{**}_{t-1(4)}$ (.0539) (.1908) (.0899)	.9741
2. Gram	$X_t = -240.5784 + .5491X^{**}_{t-1} + 2.3220W^{*}_{t(2)} + 15.9604P^{**}_{t-1(4)}$ (.0908) (1.0229) (6.9285)	.8207
3. Rape and mustard	$X_t = 2.2869 + .2385X^{*}_{t-1} + .6019W^{**}_{t(2)} + .6495P^{*}_{t-1(2)}$ (.1717) (.1884) (.2751)	.7055
4. Bajra	$X_t = 200.3879 + .5348X^{**}_{t-1} + 4.3384W^{**}_{t(2)} + 3.7516P^{*}_{t-1(2)}$ (1139) (1.2341) (1.9930)	.8596
5. Maize	$X_t = -6.1728 + .7001X^{**}_{t-1} + .1527W_{t(1)} + .1188R_{t-1(3)}$ (.1248) (10.8461) (.045)	.8378
6. Paddy	$X_t = 3.4001 + .9928X^{**}_{t-1} + .1941W_{t(2)} + .6364P_{t-1(4)}$ (.0627) (.6187) (.3349)	.9640
7. Sugarcane	$X_t = -27.8363 + .6466X^{**}_{t-1} + 12.2990W^{*}_{t(1)} + 1.0638P^{**}_{t-1(3)}$ (.0915) (6.5869) (.2706)	.8926
8. American cotton	$X_t = -39.6940 + .5841X_{t-1} - .1359W_{t(2)} + .4631P_{t-1(4)}$ (.1806) (.6126) (.1816)	.7017
9. *Desi* cotton	$X_t = -114.2089 + 32.7652W_{t(1)} + 1.9448P_{t-1(3)}$ (11.4646) (.3974)	.6705
	$X^d_t = -23.2445 + .4495X^{*}_{t-1}$ (.1501)	.4696

Note: Data used 1952-53 through 1967-68 for all crops except gram (omitting 1965-66 due to abnormal year). Standard errors are presented in parentheses.

* Significant at 5 per cent level of significance ** Significant at 1 per cent level of significance.

normal weather. The predicted area for each year became the independent variable in place of lagged area in estimating regression equation for the next year. This procedure was essentially the same as using recursive programming results in year 't' as data for t—1. In that sense the results of these two models were somewhat comparable.

Recursive programming model for each subsequent year used projected data and the flexibility constraints were imposed on the solution for the preceding year. Other constraints were assumed or projected as explained in the methodology section. The results of area and production are presented in Tables XIII and XIV respectively.

Recursive programming model showed an increasing tendency in the area and production of all high-yielding cereal crops except gram in which the trend is clearly declining. Cotton, sugarcane, rape and mustard also showed slightly rising trend in area and production of these crops. The regression model showed a declining trend in sugarcane, American cotton and somewhat constant area of maize, desi cotton, rape and mustard and bajra. It exhibited increasing trend in wheat, paddy and gram.

The examination of production estimates of wheat, bajra, maize, paddy, sugarcane and cotton would reveal that regression model projected the historical facts, while recursive programming results incorporated the influence of recent farm technology being adopted in Haryana agriculture. The Nerlovian model's adjustment coefficients played the role of flexibility coefficients in recursive programming model, but it neither treats the yield improvements empirically nor the interdependence of crop alternatives. In this context the good fits of regression equations and the statistical significance of the regression coefficients per se did not guarantee the reliability of the results. This does not imply that regression model should be discarded altogether, but some of the difficulties of regression models could

Table XIII - Estimates of Area of Major Crops in Haryana: A Projection Test (1968-69—1973-74)

(area in thousand hectares)

Crop	1968-69		1969-70		1970-71		1971-72		1972-73		1973-74	
	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.
1. Wheat	843	832	887	867	919	904	945	942	971	982	991	1024
2. Gram	1170	1094	1240	1128	1288	1126	1304	1059	1299	996	1297	939
3. Rape and mustard	194	227	203	238	207	249	210	245	209	237	205	248
4. Bajra	794	813	816	842	832	816	848	846	835	877	834	851
5. Maize	113	105	111	116	112	128	111	141	111	153	111	169
6. Paddy	237	205	255	215	274	226	293	238	312	250	330	263
7. Sugarcane	135	183	130	195	129	180	130	192	128	212	129	226
8. American cotton	131	125	124	135	123	124	120	134	119	131	119	120
9. Desi cotton	90	99	94	105	98	112	100	119	97	126	97	119

Table XIV - Estimates of Production of Major Crops in Haryana: A Projection Test (1968-69— 1973-74)

(production in thousand tons)

	1968-69		1969-70		1970-71		1971-72		1972-73		1973-74	
	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P.	Regression	R.P	Regression	R.P.
1. Wheat	1241	1248	1362	1631	1445	1956	1442	2468	1499	3261	1533	3526
2. Gram	794	843	939	705	1086	792	991	908	1022	816	1034	803
3. Rape and mustard	92.2	133.2	95.4	135.4	101.6	148.1	100.6	148.1	100.3	150.5	99.0	161.0
4. Bajra	318	414	364	416	379	450	368	473	372	530	371	634
5. Paddy	280	211	312	213	341	219	356	249	383	241	406	438
6. Sugarcane	507	676	479	711	487	659	486	700	478	813	479	942
7. American cotton	37.34	33.25	35.96	43.54	35.30	50.59	34.44	49.54	34.27	46.91	34.15	48.75
8. Desi cotton	24.84	44.27	26.32	37.83	27.15	38.04	27.70	37.98	26.87	38.46	26.77	35.79

be overcome by using recursive programming approach. Several improvements in the model are possible to explain yield and production pattern and formulation of practical policies.

LIMITATIONS

In the absence of micro data, macro data were used which need lot of refinement. Better results could be obtained by grouping the Haryana State into resource homogeneous programming units on the basis of such factors as soil type, topography, type of farm, etc.

Estimation of flexibility constraints suffered from obvious limitations of inadequate data. Improvement in flexibility constraints depends partly upon the larger information on the factors governing actual behaviour of supply system. Besides using information on the preceding years' area and a historical change coefficients, the future work should focus on improving the flexibility constraints to better represent the decision-making process into the model.

Stratification of the State into more homogeneous types and identification of additional resource and technological capacity constraints should remove much of the burden now placed on flexibility constraints.

Recursive programming model is not free from specification errors. Errors of specification are committed while defining activities, their input-output coefficients, net returns, and the constraints, etc. Adequate and requisite data should be generated to overcome these problems.

Finally, estimates and projections of the regression equations are not, strictly speaking, comparable with the estimates obtained from recursive programming model. Whereas technological changes are accounted for in the recursive programming model, the regression models used in this study do not account for the technological coefficients directly.