FORMULATION OF MATHEMATICAL MODEL FOR AGRICULTURE SECTOR

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INTRODUCTION

Agriculture is the back bone of Indian economy, and agricultural development is central to all strategies for planned development. Progress in agriculture provided the relief in the form of the country being able to meet its minimum needs for agricultural commodities. The challenges faced by agriculture sector can be met only by making the farmers, their incomes & welfare as the main focus of planning. Moreover, there is need to support infrastructural development by the state and build as economic climate for farmers investments. The extension functionaries have played major role in the development of agriculture. It is the main agency who keeps friendly relation with the farming community. In order to safeguard the interest of farmer community, it is essential to have coordination between the farmers and the department in implementing the schemes.

The total Geographical area of the state is 50.36 lakh hectares out of which 42.24 lakh hectares is under cultivation. The Agriculture in Punjab State in highly intensive in terms of land, capital, energy, nutrients, agriculture inputs and water etc. With only 1.5% of geographical area of the country, Punjab has produced about 22% of Wheat, 10% of Rice and 13% of Cotton of the total produce of these crops in the country according to the latest survey. The food grains contribution to the Central Pool is about 50-70% in case of Wheat & 40-50% of Rice. The area under cultivation is about 85% and the cropping intensity is 185%. Moreover, the fertilizer consumption is 177 kg per hectare as compared to 90 kg per hectare at the National level.

Agriculture is a complex system of various distinctive but related activities. Crop production, livestock, fishery and forestry are the main sub-sectors of the entire agricultural system. The former two constitute this study. Resource allocation to attain sectorial or overall development is vastly complex and affected by the dynamic interaction of a multitude of technical, social, economic and political variables.

This study is entirely based on econometric analysis. With the use of various econometric and other considerations, we will empirically test certain underlying relationships among the variables of the present agricultural sector model. This study will provide only skeletal information on the use of simultaneous equations system, structural and reduced forms of the equations, autocorrelation, identification and estimation technique used in this model.

The appearance of the endogenous variables along with the pre-determined variables leads to the problem that the endogenous variables on the RHS of the equations are correlated with the disturbance terms of the equations in which they appear. In this situation, the single-equation ordinary least squares models, if applied, would produce inconsistent and biased regression coefficient estimates. The instantaneous feedback mechanism, thus, requires a model that provides a simultaneous solution of the structural parameters. This task can appropriately be accomplished through the modeling of the simultaneous equations system, and hence the need of this approach, in this context efforts has been made to study the following objectives:

1. To study the Agriculture Model for Punjab.

2. To study the impact of various policy alternatives on endogenous variables of the model.

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Data Base & Analysis

The data used in this study pertained to the agricultural sector of the Punjab economy for the period of 20 years starting from 1995-96 to 2015-16 agricultural year. The crop production sector is formed of almost all foodgrains and non-foodgrain crops grown in the state. Livestock sector has also figured prominently. The data of the 'Statistical Abstracts of Punjab' were extensively used for this study. But to complete the 20 years time-series of a number of variables included in the model as well as to construct some new series, quite a large number of other sources had to be sorted out very laboriously.

Aggregate Model Equations

Out of the seven structural equations of the aggregate model as specified below, the first five were included in one block end the other two in the second block for the simultaneous estimation of the structural parameters in two different sets. This was done because of the small size of the sample period. The condition is that the number of sample observations must be greater than the number of explanatory variables for the unique solution of the parameters. The solution of all 7 equations simultaneously with the 3SLS method was not, therefore, possible since the number of pre-determined variables in the 'reduced form' of the model were greater than the number of sample observations.

Block I equations: The equations of this block have been specified as under:

1. Gross Income Equation (Crop Production Sector):
   $YAS_t = f(Q_t, WPA_t, GEAS_t, \Delta CRAFB_t, \Delta CRAFCS_t, U_7)$
2. Aggregate Agricultural Production Function:
   $Q_t = f(F_t, TR_t, ALFE_t, A_t, W_t, U_2)$
3. Fertilizers Consumption Function:
   $F_t = f(TR_t, IR_t, PF_t, AHYV_t, STCRF_t, WPA_t, U_3)$
4. Tractor Demand Function:
   $TR_t = f(F_t, ALFE_t, Wa_t, GVP_{t-1}, U_4)$
5. Agricultural Prices Equation:
   $WPA_t = f(Q_t, YAS_t, MSFNFG_t, P_t, U_5)$

Block II equations: As stated earlier, the equation on the gross cropped area of the State included in this block has been specifically formulated in order to establish linkage between various commodity sub-models and the Aggregate model. To achieve this, the seven farm prices determined endogenously earlier in their respective sub-models were made to appear as exogenous to this equation. The two equations to be determined simultaneously are:

6. Electricity Consumption (Agricultural Sector) Function:
   $ECAS_t = f(A_t, NAGRC_t, CPUE_t, TEGEN_t, U_6)$
7. Equation for the Gross Cropped Area of the State:
   $A_t = f(ECAS_t, PW_t, PPD_t, PP_t, PO_t, PMZ_t, PG_t, PCN_t, (NSDP_{na})_t, GVP_{t-1}, U_7)$

The linear form of the model was used for the solution of the structural parameters of the equations (1) to (7).

8. Income Identity:
   $Y_t = YAS_t + YLS_t$

The variables included in this aggregate level model are specified as:

Endogenous Variables

YAS_t	=	Gross agriculture income, i.e., Gross State Domestic Product (GSDP) as originated from the crop production sector in the t-th year, rupees crores.
Q_t	=	Total agricultural production in the t-th period measured as the index of 21 foodgrain and non-foodgrain crop commodities produced in the State.
C_t	=	Consumption of chemical fertilizers (N, P, K nutrients) for all crops in the t-th year, kg/hectare irrigated.
TR_t	=	Density of tractorization measured in terms of number of tractors per 1000

hectares cropped in the t-th period.

WPA_t = Wholesale prices of 21 agricultural commodities grown in Punjab for the t-th year, weighted composite index, base: 2014-15 to 2016-17 = 100

$ECAS_t$ = Electricity energy consumption in the agricultural sector of the State in the t-th period, million kilowatt hours (kwh)

A_t = Gross cropped area of the State in the t-th year, thousand hectares

Y_t = Total gross income of the agricultural sector in the t-th year as originated from the agriculture crop sector plus livestock sector, rupees crores.

YLS_t = Gross income in the t-th year as originated from the livestock sector, rupees crores – (9 in numbers)

Pre-Determined Variables

$ALFE_t$ = Total agricultural labour force as engaged in the agricultural sector measured in terms of workers (cultivators plus agricultural labourers) in the t-th year, number of workers/1000 cropped.

IR_t = Gross irrigated area of the State in the t-th year, 000' hectares

W_t = Weather measured in terms of average annual rainfall in the t-th period, in centimetres.

$AHYV_t$ = Total area under high yielding varieties of crops in the t-th period, thousand hectares.

$STCRAF_t$ = Short-term credit or fertilizers as advanced to farmers by agricultural cooperative societies of the State in the t-th year, lakh rupees.

$GEAS_t$ = Government expenditure in agriculture sector in the t-th year, i.e, expenditure actually incurred annually out of plan outlays plus government expenditure for the development of agriculture met from the revenue account of the State, rupees crores.

PF_t = Price of fertilizers in the year t, average of the prices of six important fertilizers prevalent in use, viz., urea, calcium ammonium nitrate (CAN), diammonium phosphate (DAP), superphosphate, ammonium sulphate and Muriate of Potash (MOP), rupees/kg

W_{at} = Money wages rate for agricultural labourers in Punjab in the t-th period, hundred rupees per annum.

$MSFNFG_t$ = Marketed surlpus of foodgrains and non-foodgrains in the t-th year, i.e., marketed proportion of total agricultural production, per cent.

$(NSDP_{na})_t$ = Net income of the non-agricultural sector, i.e., Net State Domestic Product at factor cost at current prices generated in non-agricultural sector in the t-th year expressed as the proportion (%) of the net income of the non-agricultural sector to the total income of the State. This variable was taken as the 'proxy' for the level of industrialization of urbanization in the State.

$\Delta CRAFB_t$ = Annual change in the per hectare credit advanced to farmers by commercial banks in the State in the t-th year, rupees/hectare cropped.

$\Delta CRAFCS_t$ = Annual change in the per hectare credit advanced to farmers by cooperative societies in the State in the t-th year, rupees/hectare cropped.

$NAGRC_t$ = Number of agricultural power consumers in the State in year t. This number in the majority of cases is equivalent to the number of electric generated tubewells in the State, numerical units.

$CPUE_t$ = Cost per unit of electricity as being charged from the farmers of the State in the t-th period, paise/unit of electricity.

$TEGEN_t$ = Total electricity power generated in Punjab in the t-th year, million kwh

P_t = General price index in the t-th period calculated as the index of 50 important agricultural and industrial prices in the State, index base: 2014-15 to 2016-17 = 100

PW_t, PPD_t, PP_t, PO_t, PMZ_t, PG_t, PCN_t = Prices of wheat, paddy, pulses, oilseeds, maize, gur and cotton, respectively in the t-th period, rupees/quintal.

A_{t-1} = Gross area cropped of the State during the preceding year, 000' hectares.

GVP_t = Gross value (rupees) productivity per hectare cropped in the t-th year calculated as:

$$GVP_t = \sum_{i=1}^{n} P_{it} Q_{it} / \sum_{i=1}^{n} A_{it}$$

i = 1, 2, ..., n crops

Where,

P_t = Prize of the i-th crop in the t-th year, rupees/quintal

Q_{it} = Physical output of the i-th crop in the t-th year, 000' metric tonnes × 10

$\sum_{i=1}^{n} P_{it} Q_{it}$ = Sum total of the value of all 'n' crops in year t, rupees

$\sum_{i=1}^{n} A_{it}$ = Sum total of the area under all 'n' crops in year t

GVP_{t-1} = Gross value productivity per hectare in the previous year, rupees/hectare cropped – (25 in numbers)

U_1, U_2, U_3, U_4, U_5, U_6 and U_7 are the stochastic disturbance terms of the equations included in the aggregate model.

The subscript 't' is dropped from the variable symbols when they appear in the subsequent chapters.

Econometric Considerations

This study is entirely based on econometric analysis. With the use of various econometric techniques and other considerations, we have empirically tested certain underlying relationships among the variables of the present agricultural sector model. This study will provide only a skeletal information on the use of simultaneous equations system, structural and reduced forms of the equations, autocorrelation, identification and the estimation technique used in this model.

The structural parameters of this aggregative model as estimated through the 3SLS estimator using time-series data for the period 1995-96 to 2015-16 are presented in Table 5.1 for Block I model equations and in Table 5.3 for Block II model equations. The estimated elasticities at the variable means for endogenous variables of Blocks I and II equations with respect to their respective explanatory variables have been reported in Tables 5.2 and 5.4, respectively. The equation-wise results are discussed as under:

Gross Income Equation (Crop Production Sector)

As stated earlier, the Gross State Domestic Product (GSDP) as originated from agricultural (crops) sector was taken as the State level gross income. Thiis was endogenised on technical, economic, institutional and Government policy factors such as agricultural production (technical factor), agricultural production (technical factor), agricultural prices (economic factor), development expenditure by the Govt. in agriculture sector (Govt. policy factor) and credit advanced to farmers by commercial banks as well as by cooperative societies (institutional factors). These five exogenous variables jointly explained a very high variation of 99.41 per cent in the gross income of the State. The d-statistic worked out to 2.0964 indicating absence of negative serial correlation in the errors of this equation.

The parameters on production, agricultural prices and developmental expenditure all came out to be highly significant at 0.01 probability level. In absolute terms, we could interpret that

agriculture sector income would significantly increase by a striking amount of Rs. 7.06 crores when the index of agricultural production went up by 1 per cent point, other things remaining the same. Similarly, if composite price index of foodgrains and non-foodgrains (comprising of 21 agricultural commodities) was increased by merely a 1 per cent point, the State gross income would significantly go up by an impressive amount of 3.22 crores rupees, on an average. The developmental expenditure incurred by the Govt. out of planned and non-planned outlays played quite a significant role in increasing the gross domestic product of the State. An amount of rupees 1 crore injected into the agricultural sector would generate a return of rupees 4.26 crores, on the average, ceteris paribus. However, credit advanced to farmers by commercial banks and cooperative societies did not show significant effect on the state gross income.

Table 5.2 shows that the elasticities of the state gross income with respect to agricultural production, agricultural prices and developmental expenditure were estimated at 0.8790, 0.4381 and 0.1121, respectively. This implied that the State gross income was more elastic to agricultural production than to the other two variables, though the gross income still remained less elastic to each of the latter variables. A 10-per cent increasse in each of these three variables would cause 8.8, 4.4 and 1.1 per cent addition in the gross income of the state.

Aggregate Production Function

The agricultural production function at the aggregate level was formulated taking capital inputs like fertilizers, tractors, human labour use and land as explanatory variables. Weather in terms of rainfall was also included in the explanatory variables. The explanatory power of this function was found to be as high as 97.87 per cent. The value of the d-statistic showed that the errors of this function were free from auto-correlation.

The parameter on the tractor use and gross cropped land came out to be significant at 0.05 and 0.01 probability levels, respectively. The index of agricultural production would increase by about 1.8 points in response to an increase of 1 tractor per 1000 hectares cropped. Likewise, the production index would be up by about 0.04 per cent points, if gross cropped area of the State was increased by 1000 hectares. Surprisingly enough, the parameter of the most important capital input factor, fertilizers, did not come out to be significant, though it carried an expected positive sign. This may be due to aggregation bias, since index of agriculture production included almost all foodgrain and non-foodgrain crops, whereas chemical fertilizers were not used for all crops. These biases did not permit the fertilizer variable to establish its legitimate role in increasing the overall production in the state. Of course, the fertilizers usage has displayed a significant role in increasing the production of various crops as has been observed in the analysis of commodity sub-models. Also, the labour force engaged in agricultural production activities did not play its role in a significant manner. This was probably due to the low productivity of human labour in the agricultural sector of the State economy. The average number of workers engaged in the agriculture sector of the state has been estimated at 430 per 1000 cropped hectare, which seemed to be on the higher side when compared to the position of other developed areas of the world. This, however, did not suggest that workers engaged in agriculture sector were surplus. Rather, there has been a general feeling of the shortage of farm labour in Punjab. The influx of labourers from other states to Punjab at the time of sowing and harvesting periods of wheat and paddy, in particular, stands a testimony to this observation.

Agricultural production was highly elastic to the total land cropped in the State. A 10-per cent rise in the cropped area would expand production by about 18.7 per cent, other things being equal. The production was found to be less elastic (though significant) to the increase in tractor density. The aggregate output showed an inelasticity to the use of fertilizers, which seemed to be somewhat an erratic outcome in so far as the high productivity of this input was concerned. Similarly, the production was found to be less elastic to the existing level of employment of agricultural labour force, the elasticity being 0.4316.

Fertilizers Consumption Function

Fertilizers consumption was determined taking tractor density, irrigation intensity, price of fertilizers, are under high yielding varieties, short term credit to farmers for purchasing fertilizers and

agriculture price index as explanatory variables. These six variables together explained 98.56 per cent variation in the consumption of chemical fertilizers. The d-statistic was estimated at 2.1938 indicating non-autocorrelated errors in this function.

The parameter on the intensity of irrigation came out to be significant at 0.01 probability level. The average price of fertilizers had an inverse relationship with the fertilizers usage and this relationship was highly significant at 0.01 probability level. The price increase would, thus, prove as a disincentive to farmers for increasing fertilizers consumption. The short-term credit advanced to farmers by cooperatives played quite a significant role (the parameter of credit variable being significant at 0.05 probability level) in increasing the usage of fertilizers in the State. Fertilizers are mainly used in growing of the high-yielding varieties. Since most of the area is already under HYV's, its effect could not be brought out significantly. It was noticed that the increase in agricultural product prices has motivated Punjab farmers to increase the usage of fertilizers. The impact was found to be significant at 0.10 probability level.

The fertilizers usage was found to be highly elastic to irrigation. The usage would increase by about 18 per cent in response to a 10-per cent increase in the intensity of irrigation. This finding is of immense importance since fertilizers use is extremely associated with water and, thus, water would be the 'sole saviour' of Punjab agriculture. Another important result of far-reaching implications was that the fertilizers consumption significantly decreased by about 6 per cent in response to a 10 per cent rise in the average price of fertilizers. The fertilizers consumption would go up by about 2.6 per cent as a result of a 10-per cent increase in the credit advanced to farmers for purchasing fertilizers. Likewise, a 10-per cent uptrend in the farm product prices would induce farmers to increase the usage of chemical fertilizers by about 4.9 per cent. The usage of fertilizers was highly inelastic with respect to tractor use and area under high-yielding varieties of crops, the letter result seemed to be somewhat erratic.

Tractor demand function

The density of tractorization measured as the number of tractors per unit of area cropped was endogenised by incorporating agricultural wages, gross value productivity per hectare lagged by one year, agricultural labour force and fertilizers use as the four explanatory variables in the function. Together, these variables explained 99.10 per cent variation in the tractor demand. The value of the d-statistic indicated that the errors were not autocorrelated.

The parameter on agricultural wages and per hectare gross value productivity both came out to be highly significant at 0.01 probability level. These two variables were found to be the main determinants of increasing demand of tractors. With the increase in the agricultural wages, which reflects higher cost of labour, the farmers showed their inclination to increase the level of mechanization on their farms. Similarly, the increase in per hectare gross value productivity in the previous year would induce farmers to increase the density of mechanization on their farms. This has reflected that the increase in both yields and prices involved in calculating the value productivity have jointly played a significant role in increasing the level of farm mechanisation. Positive sign on the parameter of fertilizers usage indicated its complementarily with tractorisation, the relationship though was not a significant one. The tractorization was found to be positively and significantly (at 0.20 probability level) related to the agricultural work force.

The density of tractorisation was found to be responsive by 7.7 and 7.1 per cent as a result of 10-per cent increase in each of the farm labourer's wages and land productivity. Though significant at lower level of 0.20 probability the tractor demand per 1000 hectares was highly elastic to the farm labour utilization.

Agricultural Prices Equation

The overall weighted index of agricultural prices is comprised of the prices of 21 agricultural commodities which included all important fodgrains and non-foodgrains grown in the State. This variable was determined taking agricultural production, agricultural income, marketed surplus of foodgrains and non-foodgrains and index of general prices as the explanatory variables. The extent

of variation in agricultural prices as explained by these four explanatory variables was as high as 98.93 per cent, indicating very strong explanatory power of the equation. The value of the d-statistic suggested no evidence of positive autocorrelation in the errors. The increase in the total agricultural production would significantly depress agricultural prices, the parameter on production being significant at 0.10 probability level. The increase in the agricultural prices was significantly associated with the increase in money income. As a result, general level of prices would increase which would further cause an increase in agricultural prices. The significance (at 0.01 probability level) of the parameter on the index of general prices very much included in this equation itself supported this contention. A 1-point increase in the index of general prices would cause 0.46 per cent point increase in the index of agricultural prices. The increase in the marketed surplus of agricultural commodities (foodgrains and non-foodgrains) also depressed agricultural prices, though not in a significant way.

The elasticity of agricultural prices with respect to agricultural production was estimated at -0.2893, which indicated that agricultural prices were negatively less elastic to the increase in the aggregate output. The composite level of agricultural prices was found to be positively and significantly responsive by about 4.8 per cent as a result of 10-per cent increase in the State gross income, ceteris paribus. The agricultural prices would increase by about 5.2 per cent as a result of a 10-per cent increase in the level of general prices. This has clearly revealed that the hike in agricultural prices could also be the result of inflationary movement in the prices of industrial and other commodities. The prices were negatively inelastic to the increase in the marketed surplus of foodgrains and non-foodgrains in the State.

Electricity Consumption Equation (Agriculture Sector)

Electricity power consumption in agriculture sector was endogenised by including gross cropped area of the State, total number of agricultural consumers, cost per unit of electricity and total electricity generated in the State as exogenous variables in this function. Together, they explained 98.24 per cent of variation in the total consumption of electricity in agricultural sector of the Punjab economy. The d-test was inconclusive to confirm about the existence or non-existence of the autocorrelation of the errors in this equation (Table 5.3).

The parameter on the gross cropped area and the total electricity generated both came out to be significant at 0.01 and 0.025 probability, levels, respectively. an increase of 1000 cropped hectares would increase the consumption of 4.43 lakh units of electricity which worked out to 443 units of electricity per hectare of cropped land. The increase in the consumption of electricity in agricultural sector was estimated at about 1.75 lakh units of electricity if there was an increase of 1 million KWh in the total power generated in the state.

The parameter on the cost per unit of electricity for the agricultural sector was negatively significantly at 0.10 probability level. This could be a finding of very far-reaching implications. It is so because a small increase of 1 paise per unit of electricity in the agricultural sector would compel farmers of the State to reduce the consumption of electricity by a very striking figure of 9.306 million kilowatt hours at the aggregate level. Power consumption in agricultural sector though had increased with the increase in the number of agricultural power consumers, yet the increase was not found to be significant.

Table 5.4 shows that the electricity consumption was highly elastic to the increase in the gross cropped area. A 10-per cent increase in the cropped area would accelerate power consumption in the agricultural sector by about 25.5 per cent, ceteris paribus. An additional power consumption of 7.3 per cent would be provided to the agricultural sector, if there was a 10-per cent increase in the total generation of electric power in the State. When distribution aspect was also taken into account, it was found that the electricity consumption was quite inelastic to the increasing number of agricultural power consumers, indicating a very sluggish supply for increasing demand of power in the agricultural sector.

Gross Cropped Area Response Equation

This equation was formulated in order to integrate various crop commodity sub-models with the aggregate model at the State level. It was done by taking prices of various commodities as the exogenous variables along with some other relevant determinants of cropped area. These determinants were electricity consumption in the agricultural sector, net income of the non-agricultural sector, which was considered a 'proxy' for industrialisation or urbanisation and gross value productivity per unit of area in the agricultural sector. These variables jointly explained 97.09 per cent of variation in the gross cropped area of the State. The D-W test was inconclusive to confirm the presence or absence or absence of autocorrelation in the errors of thiis equation. the alternative h-statistic could not be calculated as the formula did not hold good a test the auto-correlation in the errors of this equation.

The parameter on the electricity consumption variable was found to be highly significantly at 0.025 probability level. A rise of 1 million units of electricity consumption in the agricultural sector would induce farmers to bring about 965 hectares more land under crops. This has clearly reflected that the intensity of multiple cropping could be enhanced with the increasing consumption of energy in the agricultural sector. The parameters on the wheat and paddy prices were other significant at 0.10 probability level. The farm harvest prices of pulses, oilseeds, maize and gur were all found to be non-responsive to land allocation, their parameters being not significantly different from zero. The effect of price of cotton on the total cropped area was positive and significant though at a very low level of 0.20 probability. The parameter on the proportion of net income of the non-agricultural sector though was not significant, yet carried an expected negative sign. This was indicative of the declining trend in the cropped area over years as a result of increasing industrialisation or urbanization in the State. The most interesting finding of this analysis was that the gross value productivity per hectare showed an inverse relationship with the gross cropped area of the State, the parameter of the former being negatively significant at 0.10 probability level. It was found that the gross cropped area of the State would decline by a striking magnitude of about 68 thousand hectares as a result of 100 rupee increase in the gross productivity per hectare. This phenomenon could be termed as very plausible as well as desirable because of the reason that with the improvement in the land augmented technologies less area of land would be needed to get the same or increased level of returns per unit area of land.

Table 5.4 shows that the cropped area was though significant, yet less elastic to the increase in the electricity consumption. It was found to be positively less elastic to wheat and paddy prices, and negatively or positively less elastic to the increase in other prices included. Te total cropped area would decline by about 2.7 per cent in response to a 10-per cent increase in the value productivity per hectare.

The coefficient of the lagged cropped area did not significantly influence the current year's cropped area. The coefficient of adjustment was estimated as 0.9341, which was quite close to unity indicating that the optimal adjustment in the total cropped area was immediate, and short-run and long-run elasticities would almost identical.

Table 5.1 Three-stage lease squares (3SLS) parameter estimates, their SE's and other related statistics for simultaneous equations of the aggregate agricultural sector model of Punjab (Block I Equations), 1995-96 through 2015-16

Endogenous variables	Exogenous variables	Units of variables	Parameter estimates	Standard errors	t-values	other related statistics
YAS	Intercept	--	-495.6912***	64.0472	7.739	R^2 = 0.9941
	Q	Index, base: triennium ending 2016-17 = 100	7.0591**	0.9265	7.619	F = 473.957
	NPA	Index, base : 1967-70 = 100	3.2240***	0.8486	3.799	p = -0.0505
	GEAS	Rupees crores	4.2588***	1.0794	3.945	d = 2.0964
	ΔCRAFB	Rs/hectare cropped	0.0911	0.4715	0.193	
	ΔCRAFCS	Rs/hectare cropped	0.0212	0.2499	0.085	
Q	Intercept	--	-205.2364	176.9409	1.160	
	F	kg/hectare irrigated	0.0072	0.1577	0.046	R^2 = 0.9787
	TR	No./1000 hectares cropped	1.7981**	0.8505	2.114	F = 128.665
	ALFE	No./1000 hectares cropped	0.1431	0.3162	0.453	p = 0.0478
	A	000' hectares	0.0436***	0.0101	4.317	d = 1.8097
	W	Rainfall in cm	0.0146	0.1595	0.092	
F	Intercept		-87.7562****	31.6021	2.682	R^2 = 0.9856
	TR	No./1000 ha cropped	0.2613	2.1135	0.124	F = 148.21
	IR	000' hectares	0.0340****	0.0104	2.923	p = -0.1050
	PF	Rs/kg	-14.9932****	2.9576	5.069	d = 2.1938
	AHYV	000' hectares	0.0016	0.0032	0.500	
	STC RF	Rs/Hectare	0.1752**	0.0977	1.793	
	WPA	Index, base: 1967-70 = 100	0.2587*	0.1523	1.699	
TR	Intercept		-15.5314*	10.9185	1.422	R^2 = 0.9910
	F	kg/ha irrigated	0.0037	0.0154	0.240	F = 411.914
	ALFE	No./1000 ha cropped	0.2040[a]	0.0255	0.941	p = 0.3842
	WA	Hundred rupees p.a.	0.3485****	0.1239	2.813	d = 1.9639
	GVP-1	Hundred rupees / ha	0.2983****	0.0906	3.292	
WPA	Intercept		48.5399	14.4140	3.368	R^2 = 0.9893
	Q	Index, base: triennium ending 2016-17 = 100	-0.3158*	0.2122	1.488	F = 346.730
	YAS	Rupees crores	0.0646****	0.0231	2.796	p = 0.00458
	MSFNEG	Lakh in m. tonnes	-0.0360	0.1149	0.313	d = 1.8139
	P	Index, base: 1967-70=100	0.4591****	0.1100	4.174	

*, **, *** and *** Significant at 0.10, 0.05, 0.025 and 0.01 probability levels, respectively
a denotes significant at 0.20 probability level.

Table 5.2 Estimated elasticities of endogenous variables of the Aggregate Agricultural sector model with respect to their exogenous variables at the variable means, 1995-96 through 2015-16 period

Elasticity of		With respect to	Elasticity estimates (Short-run)
Gross income	1.	Agricultural production	0.8790
	2.	Agricultural prices	0.4381
	3.	Govt. expenditure for the development of agricultural sector	0.1121
	4.	Annual Change in the Credit advanced to farmers by banks	0.0036
	5.	Annual change in the credit advanced to farmers by cooperative societies	0.0005
Agricultural Production	1.	Consumption of fertilizers	0.0041
	2.	No. of tractors per 1000 hectare cropped (tractor density)	0.1280
	3.	No. of workers engaged in agricultural sector per 1000 hectare cropped	0.4316
	4.	Gross cropped area of the State	1.8708
	5.	Weather (in terms of rainfall)	0.0064
Consumption of fertilizers	1.	No. of tractors per 1000 hectare cropped (tractor density)	0.0323
	2.	Gross irrigated area of the state	1.8047
	3.	Price of fertilizers	-0.6025
	4.	Area under high yielding varieties of crops	0.0485
	5.	Short term credit advanced to farmers	0.2580
	6.	Agricultural prices	0.4905
Demand of Tractors	1.	Consumption of fertilizers	0.0299
	2.	No. of workers engaged in agricultural sector per 1000 hectares cropped	1.0165
	3.	Annual wages of agricultural labourers	0.7691
	4.	Gross value productivity during the preceding year	0.7147
Agricultural prices	1.	Agricultural production	-0.2893
	2.	Gross income of the agricultural sector	0.4753
	3.	Marketed surplus of foodgrains and non-foodgrains	-0.0173
	4.	General price index	0.5188

Table 5.3 Three-stage lease squares (3SLS) parameter estimates, their SE's and other related statistics for simultaneous equations of the aggregate agricultural sector model of Punjab (Block I Equations), 1995-96 through 2015-16

Endogenous variables	Exogenous variables	Units of variables	Parameter estimates	Standard errors	t-values	other related statistics
YAS	Intercept	--	-2471.9551****	775.0445	3.189	R^2 = 0.9824
	A	000' hectares	0.4433****	0.1462	3.032	F = 209.126
	NAGRC	Numbers	0.8596	1.7147	0.501	p = 0.1702
	CPUE	Paise/unit of Electricity	-9.3056*	5.6343	1.652	d = 1.5070
	TEGEN	Million Kwh	0.1748***	0.0697	2.508	
A	Intercept	-	4238.8297***	1708.1568	2.482	
	ECAS	Million Kwh	0.9648***	0.3836	2.515	
	PW	Rs./quintal	10.8824*	7.4107	1.468	R^2 = 0.9709
	PPD	Rs./quintal	12.7629*	7.8975	1.616	F = 24.288
	PP	Rs./quintal	-1.1148	1.6812	0.663	p = -0.2282
	PQ	Rs./quintal	-1.1793	1.4545	0.811	d = 2.3896
	PHZ	Rs./quintal	1.5150	3.2320	0.469	h = Not possible
	PG	Rs./quintal	0.8694	1.1528	0.754	
	PCN	Rs./quintal	1.8038[a]	1.3440	1.342	
	NSDPna	Per cent	-8.8991	17.4322	0.510	
	GVP-1	00' Rs/ha cropped	-67.7198*	40.7789	1.661	
	A-1	000' hectares	0.0659	0.3429	0.192	

*, **, *** and *** Significant at 0.10, 0.05, 0.025 and 0.01 probability levels, respectively
a denotes significant at 0.20 probability level.

Table 5.4

Estimated Elasticities of the Endogamous Variables of the Aggregate Agricultural Doctor Model with Respect to their Respective Exogenous Variables at the Variable Means, 1995-96 through 2015-16 period

(Block II Model)

Elasticity of :	With respect to :		Elasticity estimates (short-run)
Elasticity consumption in agricultural sector	1.	Gross cropped area of the State	2.5925
	2.	Number of agricultural power consumers	0.1447
	3.	Cost per unit of electricity	-0.1154
	4.	Total electricity generated in the State	0.7432
Cross cropped areas of the State	1.	Electricity consumption in agricultural sector	0.1650
	2.	Farm harvest price of wheat	0.1914
	3.	Farm harvest price of paddy	0.1707
	4.	Farm harvest price of pulses	-0.0352
	5.	Farm harvest price of oilseeds	-0.0439
	6.	Farm harvest price of maize	0.0234
	7.	Farm harvest price of gur	0.0218
	8.	Farm harvest price of cotton	0.0860
	9.	Net State Domestic product of the non-agricultural sector	-0.0682
	10.	Gross value productivity during the preceding year	-0.2693
	11.	Gross cropped area lagged by one year	0.0649

Agricultural production (crops), agricultural prices and developmental expenditure incurred by the government in agricultural sector all contributed significantly towards increasing the gross income of the crop production sector. Medium and long-term credit advanced to farmers by banks and cooperatives though showed an expected positive sign, did not come out to be significant because of the jumpy nature of the capital investment made out of these credits and also because of the existence of large variation in the data series on credit.

Ceteris paribus, the agricultural production was highly elastic to the total cropped area of the State, the elasticity being 1.87. The index of agricultural production significantly went up by 1.8 points in response to an increase of one tractor per 1000 hectares cropped. Surprisingly, the parameter of the most important input factor, fertilizers, did not come out to be significant, though it carried an expected positive sign. This seems to have happened due to the presence of large variation in fertilizers data series as well as due to aggregation bias, since index of agricultural production included almost all foodgrain and non-foodgrain crops, wheras chemical fertilizers variable to establish its legitimate role in increasing the overall production.

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