Vol XXXII
No. 2

APRIL-
JUNE
1977

ISSN 0019-5014

# INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

sources other than crop production to the total income, operated size of holdings and percentage of cash expenditure to the total expenditure were the major characteristics which classified the defaulters into wilful and non-wilful groups. However, the utilization of loan and operated size of holdings were the major characteristics which classified the borrowers into defaulters and non-defaulters and into wilful and non-wilful defaulters, respectively.

The discriminant function would be useful to the financial institutions in order to assess the degree of risks involved (credit-worthiness) with the loan applicants. A lendee can with confidence put his application for the loan on the basis of characteristics (especially those characteristics which make a lendee non-defaulter or non-wilful defaulter) which he possesses. For a public policy-maker, however, the function could indicate the factors which reduce the credit-worthiness of individuals (especially those contributing to the non-wilful defaults) and which, therefore, need to be suitably altered to improve their credit-worthiness and, thus, ensure a larger flow of credit to such individuals.

U. K. PANDEY AND
M. A. MURALIDHARAN*

## APPLICATION OF LINEAR PROGRAMMING MODELS IN INDIAN AGRICULTURE—SOME FALLACIES

Programming models are by now a master tool in production economics. The property of these models to enable the users to conveniently handle several hundred or several thousand variables and constraints explains, in itself, the tremendous success of their first appearance 30 years ago. In principle, almost any economic problem can fit with the general formulation of the programming problems:

$$\text{Maximize } f(X),\ X = \{ X_1 \ldots\ldots X_i \ldots\ldots X_m \} \,/\, g_j(X) \leqslant 0,\ j = 1,2 \ldots n.$$

The above is termed as a linear programming (LP) model if the f and g's are of degree one in X and the components of X are all real variables. Because of the popular and widespread availability of computer routines for solving LP models, this sub-class of programming models has become very popular all over the world. These have been widely used by the agricultural economists interested in farm planning and development. In India also, since the first use of LP models to farm planning by Desai(1), many researchers have widely used such models in varying conditions all over the country. In the majority of the applications, LP has been used to work out optimum farm plans, with and without borrowing of capital and hiring of labour, and to indicate the departures between the existing and optimum farm plans with

*Assistant Professor of Agricultural Economics, Department of Economics, Haryana Agricultural University, Hissar, and Agricultural Economist (Marketing), Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi-12, respectively.

a view to suggest ways to bridge the gap between the two for improving farm incomes.

In spite of the fact that this technique is very popular and has been widely used for farm planning in this country, there still remain certain confusions regarding its correct use. The problems have often been incorrectly formulated. Obviously, incorrect formulation of any problem cannot lead to precise results often sought by research studies.

An attempt is made in this paper to point out certain important fallacies in regard to the use of maximization LP models in Indian farming conditions. Specially, the following points would be discussed in an analytical way so as to help the researchers, if possible, not to misuse such a sophisticated and powerful technique in the future: (1) Use of prices associated with the variables (commonly referred to as activities by the agricultural economists), (2) Items of variable expenses treated as working capital, (3) Use of synthetic farm situations, especially those where even crop activities are also averaged for a given sample of farms, and (4) Classification of land.

*1. Use of Prices Associated with the Variables*

It is a common practice to use the returns to fixed farm resources as the prices of variables (activities) in farm planning studies. The returns to fixed farm resources are obtained by subtracting the variable expenses (referred to as working expenses in the constraints) for an activity from its gross returns, which are generally taken on per unit of land. It may be pointed out here that in many studies where the activities carry returns to fixed farm resources as the prices of the variables, capital borrowing activity has been widely used carrying a price equal to principal plus interest rate (4,5,8,9,10). For example, if the interest rate is 10 per cent per annum, then a capital borrowing activity carried a coefficient of —1.10. Obviously, such an use of the price coefficient associated with the capital hiring activity is incorrect. Common sense would reveal that from the gross coefficient of —1.10, the coefficient of —1.00 corresponding to the working capital constraint (row) in the capital hiring activity column has not been deducted. Had this deduction taken place, as it has been done for the rest of the columns (activities), the appropriate coefficient to be associated as a price with the capital borrowing activity would have been —0.10 and not —1.10.

An idea of the absurdities in the optimum plan which a price coefficient of —1.10 for capital borrowing activity ($C_k$), instead of the correct coefficient of —.10, can cause when all other activities carry the returns to fixed farm resources or net returns as their coefficients ($C_j$, $j = 1, 2, \ldots . n$; $j \neq k$), can be had by considering a LP problem as given in Table I. In this farm planning problem, a farmer having ten acres of uniform quality of land

but with no amount of owned working capital seeks maximization of total returns to fixed farm resources. It is further assumed that there exists a possibility for borrowing capital at the rate of 10 per cent per planning period so long as it is profitable and that land and working capital are the only two constraints faced by him.

TABLE I—MATRIX OF INPUT-OUTPUT COEFFICIENTS AND RIGHT HAND SIDE OF LINEAR CONSTRAINTS OF AN ASSUMED PROGRAMMING PROBLEM

| Sr. No. | Type of constraint | (Rs.) $C_j \rightarrow$ | 500 | 300 | —1.10 | 0 | 0 | Right hand side | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Real activities | | | Disposal activities | | | |
| | | | Capital borrowing | | | Land | Working capital | | |
| | | | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | | |
| 1. | Land | | 1 | 1 | 0 | 1 | 0 | 10 | acres |
| 2. | Working capital | | 500 | 200 | —1 | 0 | 1 | 0 | Rupees |

The solution of the above LP problem as obtained in the final iteration would be as follows:

TABLE II—FINAL ITERATION OF LP PROBLEM CONTAINED IN TABLE I

| $C_B$ (Rs.) | Activities in the basis $X_{ei}$ | Level of activity | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ |
|---|---|---|---|---|---|---|---|
| —1.10 | $X_3$ | 2000 | —300 | 0 | 1 | 200 | —1 |
| 300 | $X_2$ | 10 | 1 | 1 | 0 | 1 | 0 |
| $C_j—Z_j$ | | 800 | —130 | 0 | 0 | —80 | —1.10 |

However, the final iteration would be as presented in Table III when $C_k = —.10$ instead of —1.10 for the problem given in Table I.

TABLE III—FINAL ITERATION OF LP PROBLEM CONTAINED IN TABLE I WITH $C_k = —·10$

| $C_B$ (Rs.) | Activities in the basis $X_{Bi}$ | Level of activity | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ |
|---|---|---|---|---|---|---|---|
| —0.10 | $X_3$ | 5000 | 0 | 300 | 1 | 500 | —1 |
| 500 | $X_1$ | 10 | 1 | 1 | 0 | 1 | 0 |
| $C_j—Z_j$ | | 4500 | 0 | —170 | 0 | —450 | —.10 |

At first instance, it may be noted that the use of the coefficient $C_k = -1.10$ (principal plus interest) instead of $-.10$ (interest only) has led to a drastic under-estimation of the value of the objective function in the optimum plan, *i.e.*, instead of the true value of Rs. 4,500, it worked out to only Rs. 800. Further, the incorrect use of the coefficient $C_k = -1.10$, *i.e.*, an interest rate of 110 instead of the actual 10 per cent, made the capital borrowing too costly and thus prevented the profitable but capital intensive activity $X_1$ from entering into the final (optimum) plan. This led to a very drastic change in the optimum activity mix, *i.e.*, instead of $X_1$ occupying all the ten acres of land, $X_2$ has covered all that area on the farm. Also due to the nature of activity selected in the optimum plan, working capital gets borrowed only at Rs. 2,000 instead of Rs. 5,000. Lastly, the estimates of marginal value productivities of resources also get distorted. Instead of true estimates of net marginal products of Rs. 450 and 0.10 per acre of land and per rupee of capital borrowed, the corresponding estimates of Rs. 80 and 1.10 were obtained by using $C_k = -1.10$ in place of $C_k = -.10$. In summary form, the comparison of results for the assumed problem as obtained by using the two approaches are presented in Table IV.

TABLE IV—COMPARISON OF RESULTS FOR LP PROBLEM OF TABLE I USING $C_k = -1.10$ AND $-.10$

| Sr. No. | Items | Price coefficient of borrowing activity ($C_k$) $-1.10$ | $-.10$ |
|---|---|---|---|
| 1. | Value of the objective function (Rs.) .. .. | 800 | 4,500 |
| 2. | Level of $X_1$ (acres) .. .. .. .. | 0 | 10 |
| 3. | Level of $X_2$ (acres) .. .. .. .. | 10 | 0 |
| 4. | Level of $X_3$ (Rs.) .. .. .. .. | 2,000 | 5,000 |
| 5. | Net marginal value product | | |
| | (*i*) Land (Rs./acre) .. .. .. | 80 | 450 |
| | (*ii*) Working capital (Rs./rupee borrowed) | 1.10 | 0.10 |

From the foregoing discussion, it may not be difficult to imagine the extent of gross fallacies contained in the results of a number of studies where the researchers, pioneering in this sophisticated technique of analysis in India, have used principal plus interest instead of using only interest as the price coefficient of the capital borrowing activity while seeking to maximize an objective function carrying returns to fixed farm resources as the prices of other activities. Such misleading results would continue appearing so long as there are some capital intensive activities ($X_j$) in the model for which $C_j < C_k a_{ij}$, $j = 1,2,\ldots. n$ but $j \neq K$, and $C_j$, $C_k$ qnd $a_{ij}$ are coefficients of prices associated with $X_j$ ($j \neq k$), borrowing activity ($X_k$) and the input coefficient of variable expenses per unit of activity $X_j$ respectively.

One might also feel tempted to use gross prices of all the variables, including that for borrowing of capital, so as to get rid of the above-mentioned under-estimation problem and deducting towards the end the amount used out of working capital available with the farmers (1,11). But we must mention that such a procedure may lead to even more erroneous results, not only by under-estimating the optimum value of the objective function but often giving entirely a different activity mix. If the relative profitability of different activities remains unchanged (slope of the objective function does not change), which may be only a special case, by taking gross returns or returns to fixed farm resources, the results of the optimum plans would be just identical. But more often, the relative profitability of different activities at once undergoes a change when gross returns are taken instead of the returns to fixed farm resources or vice versa.

In order to understand the fallacies in respect of the use of gross returns instead of the returns to fixed farm resources per unit of an activity as the prices in the objective function, let us consider the linear programming problem given in Table V.

TABLE V—INITIAL SIMPLEX TABLEAU OF LINEAR PROGRAMMING PROBLEM USING ALTERNATE PRICE COEFFICIENTS WITH THE ACTIVITIES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Gross returns (Rs.) | $C_j \rightarrow$ | 1500 | 1200 | 0 | 0 | 0 | 0 |
| Returns to fixed farm resources (Rs.) | $C_j \rightarrow$ | 1000 | 1100 | 0 | 0 | 0 | 0 |
| Type of constraints | Level | Real activities | | | Disposal activities | | |
| Resources | | Crop A $X_1$ | Crop B $X_2$ | Labour hiring $X_3$ | Land $X_4$ | Labour $X_5$ | Working capital $X_6$ |
| Land (acres) | 10 | 1 | 1 | 0 | 1 | 0 | 0 |
| Labour (man-days | 100 | 25 | 20 | —1 | 0 | 1 | 0 |
| Working capital (Rs.) | 4,000 | 500 | 100 | 5 | 0 | 0 | 1 |

The difference in the results obtained by using two different sets of prices are summarised in Table VI.

TABLE VI—COMPARISON OF RESULTS FOR LP PROBLEM OF TABLE V BY USING GROSS RETURNS AND RETURNS TO FIXED FARM RESOURCES

| Sr. No. | Items | Type of prices | |
|---|---|---|---|
| | | Gross returns | Returns to fixed farm resources |
| 1. | Value of the objective function (net returns) (Rs.) | 6,800 | 11,000 |
| 2. | Level of $X_1$ (acres) .. .. .. .. | 7.2 | 0 |
| 3. | Level of $X_2$ (acres) .. .. .. .. | 0 | 10 |
| 4. | Level of $X_3$ (man-days) .. .. .. .. | 80 | 100 |
| 5. | Level of $X_4$ (acres) .. .. .. .. | 2.8 | 0 |
| 6. | Level of $X_5$ (man-days) .. .. .. .. | — | — |
| 7. | Level of $X_6$ (Rs.) .. .. .. .. | 0 | 2,500 |
| 8. | Marginal value product of land (Rs.) .. .. | 0 | 1,100 |
| 9. | Marginal value product of capital (Rs.) .. .. | 2.4 | 0 |
| 10. | Marginal value product of labour (Rs.) .. .. | 12.00 | 0 |

It may be observed from Table VI that the set of prices consisting of returns to fixed farm resources cannot be replaced with that of gross returns, without drastic and often misleading changes in the final results.

*2. Items of Variable Expenses*

In the working capital constraint, the $a_{ij}$ input coefficients refer to variable expenses incurred in producing one unit of jth activity. It has been confused by many researchers as to what should constitute the variable expenses of an activity. For example, many studies have not included the imputed value for the home produced seed, which may often be very significant in the case of a crop like sugarcane and potato. There is absolutely no justification in doing so, in fact the right thing is to account for the imputed value of home produced seed also(1) because its opportunity cost is not just zero. It may be mentioned that such an act of not accounting for the imputed value of home produced seed would vitiate the results of optimum farm plans and the activity mix obtained may be entirely different from that obtained otherwise.

Another confusion in this regard is whether charges for the hired labour should be included in the input coefficient of variable expenses or not when labour hiring is used as a separate intermediate activity with $C_j = 0$ and labour constraints in physical terms are provided in the model. The common practice with the majority of researchers is that they include the labour hiring charges in the variable expenses of an activity. If, as is the common practice, the returns to fixed farm resources are taken as prices of the variables, such a practice would also lead to under-estimation of the optimum value of the objective function by deducting the hired labour charges twice. Hence, it may clearly be borne in mind that when labour hiring is used as a separate activity in LP model, hiring charges for labour should not be included in the input coefficient of variable expenses. One has, however, to be very careful in interpreting the marginal value product of land obtained in the final solution.

*3. Use of Synthetic Farm Situations*

In many studies synthetic farm situations have been used for applying the linear programming models. By synthetic situation is meant that resources as well as activities on a sample of farms have been averaged out to get only one representative situation.

We have an objection to the indiscriminate use of averaging the farm activities. It is likely to introduce a bias in the results, most probably underestimating the optimum value of the objective function. For example, if the sample consists of 20 farmers and each of the 20 farmers raises a certain activity, say wheat, then most scientifically all the wheat producing activities should be treated as separate activities (processes) in the LP model formulation and not to use, as has been done by many researchers, only one activity of wheat production by averaging the returns and all other input

coefficients. Such a process of averaging on the part of a researcher would exclude some most profitable activities from amongst a set of all activities available for planning. If time and computer facilities are binding, it would be a better and preferable practice to average out only those activities where the input-output coefficients do not differ by more than say 10 per cent. But even before such a step is taken, it is important that only dominant activities are considered for planning and all those activities which are dominated by others may be excluded.

It may not be out of place to mention here that averaging of resources is only a practical convenience since it may not be possible and at times it may not even be required, to consider all the farms as separate situations for planning. Therefore, it may be a better alternative to use average farm resource situation only rather than a synthetic farm situation in linear programming models.

*4. Classification of Land*

Some of the researchers seem to prefer the classification of land on the basis of suitability for different crops, *e.g.*, classifying the land as wheat land, sugarcane land, wheat and gram land, etc. There has already been a lot of controversy on classifying the land in such a way(2,3). Such a classification often gives misleading results, and hence its use should be avoided.

Here also, we would like to point out that land use capability classification may be replaced by maximum crop area constraints, whenever required for certain reasons. The best way of classifying land is undoubtedly according to its quality. Without any intention of causing embarrassment to the authors(8), we are compelled to mention that the only reason for gram land irrigated ($P_{25}$) appearing in the slack in the optimum plan in spite of availability of all scarce resources is the faulty way to classification of land.

With regard to the confusing issues relating to the use of LP models in Indian farming situations, it may be concluded that (*i*) the prices associated with capital borrowing activity/activities should correspond to the rate of interest when the objective function is to maximize the returns to fixed farm resources. (*ii*) Items on variable expenses (working capital) must include the imputed value for home produced seed also. Charges for the hired labour for a particular activity should not be accounted for in the working capital expenses if intermediate labour hiring activities and labour constraints have been provided in the LP model. (*iii*) As far as possible, indiscriminate averaging of activities in a sample of farms should be avoided. And (*iv*) land should not be classified according to land use capability but according to the quality of land.

P. L. SANKHAYAN AND BALKAR SINGH DHILLON*

*Department of Economics and Sociology, Punjab Agricultural University, Ludhiana.

## REFERENCES

1. D. K. Desai: "Increasing Income and Production on Indian Farming—Possibilities with existing Resource Supplies on Individual Farms (Application of Linear Programming Technique)," The Indian Society of Agricultural Economics, Bombay, 1963.

2. D. K. Desai, "Application of Programming Techniques to Indian Farming Conditions by S. S. Johl and A. S. Kahlon—Book Review," *Indian Journal of Agricultural Economics*, Vol. XXIII, No. 1, January-March, 1968, pp. 91-94.

3. D. K. Desai, "Note on Application of Linear Programming Techniques to Indian Farming Conditions—A Reply," *Indian Journal of Agricultural Economics*, Vol. XXIV, No. 1, January-March, 1969, pp. 95-100.

4. K. C. Dhawan and S. S. Johl, "Comparative Profitability of Dairy Enterprise in relation to Crop Cultivation on Suburban Farms in Punjab," *Indian Journal of Agricultural Economics*, Vol. XXII, No. 1, January-March, 1967, pp. 81-97.

5. K. C. Dhawan and S. S. Johl, "An Economic Analysis of Dairy Enterprise vis-a-vis Crop Cultivation in Punjab—A Case Study," *Indian Journal of Agricultural Economics*, Vol. XXIV, No. 2, April-June, 1969, pp. 53-72.

6. E. O. Heady and W. Candler: Linear Programming Methods, Iowa State University Press, Ames, Iowa, 1964.

7. Jai Krishna, "A Linear Programming Model for Selection of Crop Enterprises on an Average Farm in Western Uttar Pradesh," *Indian Journal of Agricultural Economics*, Vol. XVI, No. 4, October-December, 1961, pp. 13-21.

8. S. S. Johl and A. S. Kahlon: Application of Linear Programming Techniques to Indian Farming Conditions, Punjab Agricultural University Press, Ludhiana, 1967.

9. A. S. Kahlon and S. S. Johl, "Note on Application of Programming Techniques to Indian Farming Conditions," *Indian Journal of Agricultural Economics*, Vol. XXIII, No. 3, July-September, 1968.

10. A. C. Sharma: Mechanization of Punjab Agriculture, Eurasia Publishing House(P) Ltd., New Delhi-55, 1976.

11. A. S. Sirohi and A. C. Gangwar, "Economic Optima in Resource Allocation for the Cultivators of Kanjhawala Block," *Indian Journal of Agricultural Economics*, Vol. XXIII, No. 3, July-September. 1968.