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NOTES

ESTIMATES OF PRODUCTION FUNCTIONS IN INDIAN AGRICULTURE*

Much of the empirical research on Indian agriculture during the last decade is focused on the estimation of production function and returns to scale parameters. The emphasis on this aspect of Indian agriculture is largely motivated by the controversy regarding the efficiency of resource use in under-developed countries, with particular reference to the use of labour.[1] Another reason for the bias in favour of production function analysis would appear to be the data availability in regard to crop output and inputs. Notwithstanding the number of studies in this area of research, the parameters estimated show considerable instability and, in many cases, wrong signs, particularly, for the parameter associated with the use of animal labour. The purpose of the paper is to illustrate how important the *measurement* of the inputs and *specification* of the production function are in the estimation of the parameters and show how it is possible to derive stable estimates of the parameters. Another objective of the paper is, of course, to test the hypotheses (*i*) that resources are used efficiently so as to maximize profits; and (*ii*) that constant return to scale prevails in Indian agriculture.

The paper is divided into three sections : The model used and the assumptions made are spelled out in section I; the second section reports the empirical results; and the summary and conclusions are presented in section III.

I

The Model and the Assumptions

The characteristics of the industry studied are as follows :

A large number of farms operate in this field. They are free to choose the quantity and (crop) composition of output and they face a competitive product market. Thus the price of the product is 'given' to any individual farm. The land market is fairly competitive in so far as the hiring out of land services is common. The capital market may be somewhat imperfect owing to borrower's and lender's risks. Since we do not have any more information about the nature of the imperfection we simply assume that perfect competition prevails. The labour market is competitive in so far as labour services are freely bought and sold. There is no obvious reason why family and hired labour cannot be treated as homogeneous. Yet it may be true that hired labour calls for at least some supervisory farm labour from the family. The market for bullock services can be described as competitive so long as they can be hired (or exchanged). Finally, there are markets for seeds, manures and other inputs that are competitive. Competitive markets do not necessarily deny price variations between the observations because

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This paper was first presented at the Tenth Indian Econometric Conference held at Madurai in November, 1970 and is based on part of the empirical results (for Maharashtra State) presented in S. V. Sethuraman: Long Run Demand for Draft Animals in Indian Agriculture (unpublished Ph.D. dissertation, University of Chicago), March, 1970, Chapter III.

1. See T. W. Schultz, Transforming Traditional Agriculture, Yale University Press, New Haven, 1964, pp. 53-60, for a discussion of the controversy.

the price is 'given' only to the individual farm, yet variations between farms depend on the geographical location of the farm. Exogenous variables such as rainfall and climate are also 'given' to all farms, at a given point in time, situated in a fairly homogeneous geographic region. Fortunately, in Indian agriculture, where no major changes in relative factor prices took place at least until the mid-'fifties, it is reasonable to assume the absence of any disequilibrium in the use of factors pending adjustment.

The time period of the analysis refers to the crop season when full employment of most resources prevail.[2] New variables are constructed from the raw data and these are defined in the Appendix.

It will be noticed from the definitions that an attempt has been made in this paper to measure all the inputs in 'flow' terms since the production function concept necessarily implies a relationship between output and input flows per unit of time. Inadequate attention paid to the measurement of inputs in production function analysis would appear to explain part of the puzzling results obtained by some of the researchers in this area. Measurement of capital inputs in 'stock' terms without any adjustment for the degree of utilization in any given period, inadequate recognition of the differences in quality of inputs between different farms, etc., are examples of the errors often committed. Another point that is usually overlooked by some of the researchers is the assumption of substitutability among inputs, on which the neo-classical production function rests.

The form of the production function is assumed to be of the Cobb-Douglas type.

(1) $$Y = \text{const. } A^{a_1}\, B^{a_2}\, C^{a_3}\, L^{a_4} \exp(\gamma_i + \delta_j u_{ij})$$

$i = 1, 8$; and $j = 1, 3$ (1957, 1956, 1955).

where γ and δ denote the size and year "effects" respectively and can be interpreted as the coefficients of size and year dummies[3]; by definition $\gamma_1 = \delta_1 = 0$; and

Y = value of output in rupees per farm;

A = net area sown per farm;

B = bullock time in days per farm;

C = value of capital services in rupees per farm;

L = Labour input in days per farm; and

u = random disturbance term independently distributed with zero mean and finite variance.

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2. It was assumed that, on the average, the crop season lasts for five months in a year.

3. In the empirical results reported below, two more dummy variables were defined separately for the district and the method of collection of data to see if they produced any independent systematic shifts in the estimated production functions.

Owing to lack of sufficient degrees of freedom we shall assume that the production coefficients of factors are the same for all farms but allow the possibility of variation in the constant term. The disturbance term "u" in the production function does not include any "weather" effects because it is given to all farms within the given region. Further output follows input after a fairly long lag of time.[4] Since no data were collected in regard to the management input, dummy variables are defined for different size-groups by which the observations are classified.[5] The inclusion of size dummies in the regression not only takes care of the left out management input but also facilitates the disentangling of scale effects, if any. Similarly, the year dummies take care of weather and other exogenous effects that may be present in the data for different years. In view of the above considerations, the production function is taken to be well specified and that there is no problem of identification.[6] In the empirical work reported below, variations of the above model are also tried with a view to discovering any meaningful relationship that may exist between the output and the inputs.

II

Data Source and Empirical Results

The data utilized in the analysis were collected through farm management surveys by the Ministry of Food and Agriculture, Government of India, during the period 1954 through 1957 in the State of Maharashtra.[7] Data were collected from approximately 600 farms in 32 villages for each of the three years.[8] About a third of the data thus collected was through "cost accounting" approach while the rest obtained through "survey" approach using questionnaires. The analysis presented below is, however, based on the grouped data, grouped by size-groups of farms, method of collection of data (cost accounting or survey method), districts and years since ungrouped data were not accessible.[9] Thus, the production functions were estimated using the eighty independent observations that were available.[10]

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4. For additional discussion on the question of specification, see Zvi Griliches, "Specification Bias in Estimates of Production Functions," *Journal of Farm Economics*, Vol. 39, No. 1, February, 1957, pp. 8-20 ; and Zvi Griliches, "Estimates of the Aggregate Agricultural Production Function from Cross-sectional Data," *Journal of Farm Economics*, Vol. 45, No. 2, May, 1963 pp. 419-428.
5. See data sources discussed below.
6. Implicit in the above formulation of the production function are the assumptions that the discrepancy between the expected and the actual value of output is solely caused by random disturbances and the response to changes in relative prices, if any, is instantaneous.
7. Government of India, Studies in Economics of Farm Management in Bombay (1954-55, 1955-56, 1956-57), Directorate of Economics and Statistics, Ministry of Food and Agriculture.
8. The actual number of farms on which following analysis is based is, however, 1,381 only owing to non-collection and non-response in some years.
9. It is clear that the use of grouped data in regression analysis necessarily lowers the precision of the results, however small it may be, by virtue of the fact that the rich variations in outputs and inputs within the groups are eliminated in the process of aggregation. Generally the loss in precision due to grouping is quite small compared to the cost in terms of additional computational efforts, etc., needed for analysing the ungrouped data. See E. Malinvaud : Statistical Methods of Econometrics, North Holland Publishing Company, Amsterdam (second revised edition), 1970, pp. 281-285, for a detailed discussion of the circumstances under which the use of grouped data for regression analysis is desirable.
10. The number of observations available for analysis was only 80 instead of 96 owing to non-availability of 16 observations for the two districts by cost accounting method in 1954-55.

Estimates of the parameters in the production function are presented in Table I. When output is related to inputs including seed input, the latter appears to explain most of the variations in output leaving the role of other inputs less significant, particularly that of bullock labour as can be seen from equations 1.7.2 and 1.7.3. If, however, we exclude the value of seeds from the value of output, the equations show considerable improvement. All the coefficients have the right sign except bullocks in 1.7.2 and irrigation input. It is probably true that our measurement of irrigation is poor. In the regions under study almost all the irrigation is through wells. While the value of services from wells was excluded from the capital input to overcome complementarity between irrigation and wells, it was not possible to exclude the corresponding bullock and human labour services which are also complementary with this input. Hence, alternative regressions excluding irrigation completely but including wells in the capital input were estimated. The coefficient of capital is higher now than before as expected.

TABLE I—PRODUCTION FUNCTION FOR ALL CROPS : BOMBAY, 1954-55 TO 1956-57

Equation	1.7.2	1.7.3	1.7.8	1.7.10	1.8.1
R^2	0.95	0.95	0 94	0.93	0.93
Dependent variable ..	VO	VO	VO[a]	VO[a]	VO[a]
Constant	3.177 (0.445)	2.126 (0.527)	1.422 (0.534)	1.901 (0.492)	1.745 (0.482)
Bullock team services (value)	−0.049[b] (0.103)	0.212 (0.111)	0.370 (0.109)	0.289 (0.112)	0.308 (0.112)
Labour services (quantity)	0.155 (0.078)	0.189[c] (0.075)	0.272[c] (0.080)	0.238[c] (0.081)	0.244[c] (0.081)
Net sown area	0.329 (0.074)	0.235 (0.064)	0.248 (0.072)	0.199 (0.074)	0.191 (0.074)
Capital services (@ 3%)	0.096 (0.052)	0.079 (0.051)	0.123 (0.056)	0.199[d] (0.074)	0.180[e] (0.074)
Irrigation input	−0.004 (0.057)	−0.058 (0.056)	−0.131 (0.057)		
Seeds input (value)	0.319 (0.060)	0.236 (0.061)			
Manure input (value)	0.020 (0.017)	0.025 (0.017)	0.024 (0.019)	0.025 (0.019)	0.027 (0.019)
Bullock quality measure	0.005 (0.001)	0.005 (0.001)	0.006 (0.001)	0.005 (0.001)	0.005 (0.001)
Returns to scale.. ..	0.87	0.92	0.91	0.95	0.95

Note : All regressions with year dummies; VO=Value of output. a=Less value of seeds. b=Quantity. c=Value. d=Includes value of services from wells. e=Computed at 7 per cent rate of discount; includes value of services from wells.

The value of animal and human labour inputs appears to give a better fit to the available data than the respective quantity measures. One possible explanation for this result is that part of the quality adjustments for these inputs is taken care of by the value measure and not by the quantity measure—even in the presence of a bullock quality measure. The bullock quality is highly significant in all the regressions and thus belongs in the production function.

Interchanging the two measures of capital services based on 3 and 5 per cent discount rates, did not show any improvement in the results when introduced explicitly in the regressions.[11]

The district or sample dummies were not significant in any of the regressions. So was the case with the size dummy variables,[12] in the presence of the land input. Hence these dummies were deleted in the final regressions, to save the degrees of freedom.

III

Summary and Conclusions

The equation 1.8.1 in Table I appears to give the best fit to the data, judged from the point of view of the stability[13] and standard errors of the estimated coefficients.[14] In other words, the coefficients estimated in 1.8.1 (and 1.7.10) not only have low standard errors relative to other equations but also show 'stability' in the sense that their magnitude is virtually unaltered, no matter what other variables are included or deleted from the equation. The estimated return to scale appears to be somewhat below unity. In order to judge the efficiency of resource use we may compare the relative shares of factors implied by the equation above with the actual distribution of total cost, excluding the value of seeds,[15] averaged over samples, districts and years. The comparison is presented in Table II.

TABLE II—COMPARISON OF ESTIMATED AND ACTUAL RELATIVE SHARES OF INPUTS

Input	Estimated	Actual
Bullock and labour services	0.581	0.569
Land services	0.201	0.225
Capital services including manures and fertilizers	0.218	0.206
	1.000	1.000

Note : Estimated relative shares are based on equation 1.8.1 after adjusting the elasticity coefficients for returns to scale. Actual relative shares are computed from the published data for 1954-55 to 1956-57 after eliminating the value of seeds in total cost.

The results would appear to indicate that there were few inefficiencies in the resource use, if any, in the farms studied here.

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11. The low discount rates used above are assumed to reflect the true opportunity cost of capital prevailing in a traditional agriculture. See T. W. Schultz : Transforming Traditional Agriculture, pp. 83-101.

12. The year dummy was not significant in the regressions reported in the table.

13. Stability of the coefficients was judged from several other regressions of the same form but including alternative measures of the variables, that were estimated and not reported in the paper (since they do not provide any additional information).

14. Though the equation 1.7.10 appears to be as good as 1.8.1, the latter was chosen for the discussion presented below because the capital services in this equation are based on a discount rate of 7 per cent, which may be closer to reality. Since the coefficients estimated are virtually the same in the two equations, it hardly matters which of the two is chosen for the discussion below.

15. Value of seeds excluded from the total cost since it is excluded from the value of output used in the estimation of the production function 1.8.1.

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APPENDIX

Output : Measured in current value terms. It is gross of all inputs and includes by-products.

Land input : Measured by the net sown area in acres and thus excludes any part of the farm area which remained uncultivated throughout the year. It also excludes area under structures that may be present in a field.

Bullock services : Measured in days of 8 hours of actual work. Since bullocks are worked in pairs with one man for each pair, the variable 'bullock team services' is defined as a unit comprising one bullock-day plus half man-day. This definition is necessary in order to allow for the substitutability between factors in the production function. Correspondingly the value of bullock team services is defined to be the sum of the cost of a day's bullock labour and the value of labour for half a day.

Labour input : Measured also in days of 8 hours and excludes labour used along with bullocks only. Value of labour input is measured in rupees at the going wage rate.

Seeds and manures : Measured in current value terms.

Capital services : The current market value of different kinds of farm assets, *viz.*, wells, farm buildings and implements and machinery were converted into flow of services through "annuity" approach separately for the three categories using a length of life of 50, 25 and 8 years respectively based on the information in the published source and a rate of discount of 3, 5 and 7 per cent. Thus, three measures of capital services were constructed corresponding to the three discount rates for each of the three types of assets and finally aggregated to get the total flow of capital services. This quantity represents the potential flow through the year. To arrive at the actual utilization the above quantity was multiplied by the fraction of the year for which land was utilized (cropped) on the average.*

Irrigation input : Measured in gross area irrigated.

Prices : Price of output refers to the harvest period; price of land services, labour and bullock services evaluated at the going rate in the market; price of land and other items of capital stock also evaluated at the going market rate.

Quality measures : One measure of bullock quality is the value of the animal itself. Another measure of the same is the cost of maintenance of an animal per year. Still another measure is the ratio of value of concentrates fed to the animal to the value of other feeds. The bullock quality measure used for the regressions reported is the first one, *i.e.*, value of the animal.

Intensity of land utilization : Measured as the quotient of gross sown area (*i.e.*, net sown area plus area cropped more than once) to net sown area.

APPLICATION OF MARKOV CHAIN ANALYSIS IN SHORT-TERM DEMAND FORECASTING FOR AGRICULTURAL INPUTS†

In recent years many studies have attempted to estimate the demand for agricultural inputs like fertilizers, pesticides, and seeds, based on the area under different crops and the rate of application of the inputs. From the point of view of economic theory, the demand for an input is a derived demand and is dependent on the price of the input, price of the output for which the particular input is used, and the income level of the producers. However, in order to estimate such demand relationships it is necessary to have fairly long time series data on these variables. In the absence of such data, attempts were made to collect cross-section data on the per acre use of the inputs and the proportion of area in which the input

* If the intensity of land utilization is one then it is assumed that capital is utilized at 5/12 of the potential. In so far as the intensity of land utilization varied between observations, the fraction by which capital is utilized also varies since the rate of capital utilization=intensity of land utilization × 5/12.

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