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RESOURCE USE, EFFICIENCY, AND RETURNS TO SCALE IN PAKISTAN

A Case Study of the Peshawar Valley

by

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Empirical studies, both on North West Frontier Province (NWFP) and its constituent regions, with respect to the overall economy as well as specific segments are few. In fact, recent estimates of economic conditions for the late 1980's are totally lacking. Though studies abound that are titled to indicate that the whole Pakistan economy is covered, with few exceptions these studies never go beyond covering the Punjab and Sind provinces.[1] With this realization in mind the present study was initiated to focus on some aspects of the agricultural economy of the Peshawar Valley. The study attempts to: 1) Determine how farmers allocate their resources among different enterprises and whether they optimize. 2) Obtain evidence as to whether farms are experiencing scale economies. 3) Determine if there are differences among different farm size classes with regard to production technology.

Section I introduces the Valley's economy in relation to NWFP and summarizes some characteristics of the sample farms. Section II reviews the literature specific to resource use efficiency and scale economies, and discusses the methodology followed in this study. The empirical analysis is presented in Section III followed by conclusions in the last section.

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[1] For example see, i) Khan, M.H., "Farm Size and Land Productivity Relationships in Pakistan, Pakistan Development Review, Vol XVII, No 1, 1979. ii) Choudhry, Ghaffar et al., "Size Productivity Relationship in Pakistan's Agriculture in the Seventies," Pakistan Development Review, Vol XXIV, No 3&4, 1985. iii) Mahmood, M. and Nadeem-ul-Haq, "Farm Size and Productivity Revisited," Pakistan Development Review, Vol XX, No 2, 1981. iv) Khan, M.H. and Maki Dennis, "Relative Efficiency by Farm Size and the Green Revolution in Pakistan," Pakistan Development Review, Vol XIX, No 1, 1980.

- I -

INTRODUCTION

Peshawar Valley[2] is unique to the economy of NWFP in many respects. First, 34% of the province population is concentrated here.[3] Equally important is that it is the seat of one of the fastest growing urban centers of the country. Over the 1981-88 period, the estimated population of Peshawar Valley rose by 24.98% (or 3.125% per annum) from 2282 thousand in 1981 to 2852 thousand in 1988, due to a high birth rate and net in migration.[4] This phenomenon of dense and fast growing population has been further aggravated by the influx of Afghan refugees since the war broke in Afghanistan. By all estimates, this valley accommodated the majority of the refugees.

Peshawar Valley in Relation to NWFP Agriculture

1) **Productivity:**

Peshawar Valley occupies a major place in the economy of NWFP. Thus in 1985-86, almost 60% of the sugarcane, 25% of the tobacco, 18% of the fruit, 16% of the wheat, 13% of the vegetables and 12% of the maize of the whole NWFP were produced in the Valley.

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[2] This comprises Peshawar proper, Charsada and Nowshera administrative regions of the North West Frontier Province (NWFP). NWFP itself is one of the four provinces of Pakistan.

[3] Government of NWFP "Important District-wise Socio-economic Indicators of NWFP," Bureau of Statistics P&D Department, Peshawar 1988.

[4] Ibid.

In terms of productivity it ranks highest among the regions of the province. This derives from its highest yield per hectare in wheat, maize, sugarcane and oil seeds while at the same time keeping pace in yield/ha for other crops like tobacco, vegetables and fruit (Table I.1).

Table I.1: Area, Production and Productivity

Crop	Yield (Kg)/Hectare		Peshawar as a % of NWFP	
	Peshawar	NWFP	Area	Production
Wheat	1,776	1,204	11.1	16.4
- irrigated	2,047	1,716	.	.
- unirrigated	1,005	897	9.9	12.0
Maize				
- irrigated	1,753	1,781	.	.
- unirrigated	100	1,073	.	.
Sugarcane	41,434	39,012	55.0	58.9
Tobacco	1,945	2,005	25.7	25.9
Oil Seeds	1,500	640	1.3	3.10
Vegetables	12,842	13,962	14.6	13.4
Fruit	10,571	10,393	17.4	17.7

Source: Government of NWFP, op.cit., pp. 6-12.

2) **Use of Non-traditional Inputs:**

One of the factors, besides a high percentage of irrigated land, contributing to the comparatively high yields in Peshawar Valley is the use of modern inputs such as fertilizer. Statistics in this regard show that fertilizer use including nitrogenous, phosphate and potash, per hectare in Peshawar are twice as large as in NWFP in general.

Table I.2: Average Fertilizer Use (kg) Per Hectare, Peshawar Valley and NWFP

Type	Peshawar	NWFP	Ratio
Nitrogenous	98.3	43.70	2.25:1
Phosphate	27.1	12.30	2.20:1
Potash	6.7	2.20	3.05:1
Total	131.5	58.2	2.26:1

Source: Government of NWFP, op cit., p. 4-5.

3) **Resource Endowments:**

a) **Land:**

The Peshawar Valley is spread over 395 thousand hectares (or 7.025% of the NWFP land area). In terms of farm area, it is one of the best endowed regions of the province. For instance while the proportion of irrigated area of NWFP is 44%, the corresponding area for the Valley is 77.21%.[5]

Peshawar has a cultivated area of 195 thousand hectares (which is 11.162% of the NWFP cultivated area). Since the rural population living in the Valley is 1.43 million (according to 1981 Census estimates), cultivated area per rural person comes to 0.086 hectares per person (or 0.212 acres) as against the provincial estimate of 0.39 acres.

[5] Government of NWFP, op.cit.

According to 1985-86 estimates, cropped area in the Valley was 219 thousand hectares (which as a percent of NWFP is 12.33). Cropped area per rural person then, again assuming the 1981 rural population of 1.433 million, is 0.153 hectares or (0.3775 acres).

b) Labor:

The Valley has a total population of 2.282 million according to the 1981 Census report. However, as mentioned in the introduction, over the past decade, the Valley's population increased significantly. Depending on one's perspective, this rising population could be viewed both as a resource as well as a constraint on the development of the Valley. However, under the existing conditions when the country as a whole is trapped in a sort of low level equilibrium, this rising population, with commensurate absorption in gainful employment lacking, must be viewed not only as a constraint but a resource depleting factor.

General Characteristics Of Sample Farms

One criterion on the basis of which farms may be appropriately classified and understood is the size of farm. This may be defined either in terms of gross value of sales, operated land holding, value added, or any combination of these. Taking operated land holding as a criterion,[6] some key characteristics of the sample farms are presented below.

[6] With the convention that small farms operate (12.5 or less) acres, medium farms (12.5 - 25.5) acres and the large farms (25.5 and above) acres of farm land.

1) Resource Endowments

a) Average household size and human capital:

The average household size for the sample of farms is 14 persons. Distinguished by farm size category, this number varies. It is observed that as farm size gets larger, average household size increases. The respective figures on household size for the small, medium and large farms are 12, 16.2 and 23.3 persons.

While the figures on average household size seem very large, it may be pointed out that all families in general and farm families in particular are extended families in the Peshawar Valley. An important reason for the prevalence of extended families and hence larger household sizes is the way property, i.e., land is transferred to the sons. The usual convention is that as long as the father and in some cases the grand-father is alive families cannot separate. Rather, they get larger and larger. Another reason for the very large families in Peshawar Valley relates to the Tribal nature of its society where only force matters. People are forced to have larger families because it gives them the power to fight and defend themselves so as to retain their property, i.e., land.

b) Number of earners per farm:

While the average household size increases with farm size the opposite holds for the average number of earners per farm. Here one may hypothesize that the large farms assign more weight to education and hence more of the family members on such farms, who could otherwise work, go to school. Statistics do show some evidence in this regard.

The percentage of the population attending school, especially in the education level "11 and above" is higher on large farms (Table I.3)

c) **Average operational land holding:**

The average operational land holding is 19.05 acres for the sample farm households. Distinguished by farm size category, large deviations from the mean farm land holding are observed. Thus it may be seen that the small farms are only as large as 1/3rd of the medium and 1/7th of the large farms. With this, one would expect the average number of fragments, an indicator of land quality and inefficiency parameter,[7] to increase (Table I.3).

Table I.3: Average Household Size, Number of Earners, Literacy Status and Operational Land Holding (Acres)

Characteristics	Unit	Farms Differentiated by Size: Less 12.5	12.5-25.5	25.5 & Above	All Farms
0	1	2	3	4	5
Household Size	No.	12	16.2	23.3	14.8
Earners Per Farm	No.	3.1	4.5	5.4	3.9
Land Holding	acres	5.51	17.02	39.09	19.05
Fragment Per Farm	No.	2.43	4.52	11.83	3.66
Per Capita Land Holding	acres	0.46	1.05	1.68	1.29
Literacy:					
level 1-5	%	27	20	13	21
level 6-10		63	68	55	62
level 11 & above		10	11	32	17

Source: Farm Survey 1987-88.

[7] See Bardhan, P.K., "Size, Productivity and Returns to Scale: An Analysis of Farm Level Data in Indian Agriculture," Journal of Political Economy, Vol 81, No 6, Nov/Dec 1973, p. 1374, for the characterization of 'Farm Fragmentation' as an inefficiency parameter.

d) **Livestock holdings:**

In the Valley the different kinds of livestock raised on farms include cows, bullocks, buffaloes, sheep/goats and pack animals, mainly donkies. Mules, camels and horses are almost non-existent.

In regard to farm households owning livestock, bullocks are owned by 79.44% of the farm households. The respective figures for farm households owning buffaloes and cows are 53 and 59%. Sheep/goats are only raised by 28% of the farms while pack animals by 21.5%.

Farm distinctions across different farm size classes with respect to livestock composition are not as clear. A very mixed sort of picture emerges when such characterization is attempted. But it is amply clear that the average number of livestock per farm increases as farm size increases. The following statistics reveal this observation.

Table I.4: Sample Farms Characterized by Size and Livestock

Kind	Farms Differentiated by Size (acres) Less 12.5	12.5-25.5	25.5 & Above	All Farms
0	1	2	3	4
Cows	1.5	1.3	2.2	1.6
Female Buffaloes	1.3	2.6	6.5	2.7
Bullocks	1.4	2.0	2.5	1.7
Male Buffaloes	1.0	1.0	1.3	1.1
Sheep/Goats	1.8	2.0	6.7	3.5

Source: Field Survey 1987-88.

2) Farm Organization and Resource Use

a) Tenurial arrangements and extent of tenancy:

Owner, tenant and owner-cum-tenant type of arrangements prevail in the Peshawar Valley. The tenented farms, however, constitute the majority (52%). Distinguished across the different farm size categories, it is observed that the extent of owner farming declines as farm size increases. Thus, on the large and medium farms, cropping on "rent" or "share" basis is the dominant mode of tenurial arrangement. This may be understandable when considered in conjunction with the type of employment and preference of the large farms households for off-farm activities.

b) Time allocation of family labor:

In the language of modern household economics, the time of household members is a resource or factor of production. For poor households, it represents the dominant household resource.[8]

In the context of the Valley, on the average, the sample farms allocate 75% of their time to farm activities. However, across the different farm size classes, broad differences may be observed. Thus, we see that both the large and small farms allocate a high proportion of their time, with respective weights of 33.3% and 35.8%, to off-farm activities while medium farms only allocate 10% of their time. While the underlying rationale for this time allocative pattern is a testable

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[8] Evenson, R.E., "Time Allocation in Rural Philippine Households," American J. Agr. Econ., May 1978, p. 322.

hypothesis, tenative explanations may be ventured with regard to the small farms.

First, the small farm families are forced to work because given the size of their per capita holding, the farm income may not be enough to support them. Second, small farms are now more aware of possible improvements in living conditions than they used to be. Their expectations seemed to have changed as evidenced by the school going population on such farms. Over the past two decades if the average economic conditions in NWFP have not changed, general awareness to get better certainly has increased due to changing political conditions and information technology.

c) **Input use:**

i) Land use and intensity: Land use as well as cropping intensity[9] falls with increase in farm size implying that small farms make greater use of the land resource. In this connection it may be pointed out that with the increase in farm size, the proportion of waste land also rises, hence the land use intensity may be a biased measure of the use of land resource, i.e., large farms have lower quality land.

ii) Labor use and intensity per acre: The average labor use per acre per year is about 30 days - with a declining tendency as farm size rises. The respective figures for the small, medium and large farms are 34.25, 33.0 and 25.33 days per acre.

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[9] Land use intensity is defined as the proportion of farm land that is cultivated, i.e. land use intensity: cultivated land/farm land x 100. Cropping intensity, which is a different concept, is calculated as: cropped area/cultivated area x 100.

iii) **Bullock use:** The overall average use per acre is 4.11 days per year. The respective figures for small, medium and large farms are 4.203, 3.395 and 4.069), indicating higher bullock use by small farms.

iv) **Machinery use:** The average (tractor and thresher) use per acre is 4.79 hours per year. The size-wise distinctions in this regard follow the same pattern as noticed in the use of bullock per acre. Per acre machinery use across small, medium and large farms is respectively 4.71, 4.376 and 4.56 hours, per year.

d) **Cropping pattern:**

Figures on cropping pattern show that annual crop growing is the major farm activity, irrespective of farm size. Perennial crops, i.e. orchards may be sparsely seen only on the largest farms. Of the annual crops, wheat, sugarcane and maize account for 75% of the cropped area.

Distinguished on the basis of farm size, the small farms may be seen to have a bias towards growing wheat and maize while the medium and large farms have a high proportion of cropped area allocated to sugarcane. This, then, points to the observation that small farms are subsistence farms - farming to meet the food demands for home consumption.

- II -

LITERATURE REVIEW AND METHODOLOGY

Literature Review

The literature on resource use, farm efficiency and returns to scale may be reviewed from different perspectives. Here it will be shown 1) how the concepts of size and scale are defined,[10] 2) why productivity, in relation to scale, should be the focus of interest, 3) what is the evidence on returns to scale in agriculture and what are the different explanations advanced both in favor of increasing and decreasing returns to scale where such results have been obtained.

1) Size and scale:

Size and scale are two different notions. Returns to 'size' has to do with the economic notions of what is happening to costs (AVC as well as MC) as output is expanded. Returns to scale, on the other hand, refers to what happens to output when all input categories are changed proportionately.[11] Here all input categories means fixed as well as variable inputs. Returns to scale, then, is a long run concept. According to Debertin, in practical terms it is, however, difficult to implement the concept of "returns to scale"

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[10] See Hallam, A., Economies of Size, in Determinants of Farm Size and Structure, Robison, J. (ed.), Michigan Agricultural Experiment Station Journal Article No. 12899, 1988; for a summary of the various ways scale and size economies may be measured.

[11] See Beattie, Bruce and C.R. Taylor, "The Economics of Production," John Wiley, New York, 1985, p. 53, 40.

because a proportionate change in all inputs is seldom achieved in the real world.[12]

2) **Why productivity in relation to scale be the focus:**

As to why productivity in relation to scale be the focus of interest, Kislev and Peterson write, "Returns to scale, if they actually exist in agriculture, affect significantly both the economics of agriculture and our understanding of the farm sector."[13] p. 12.

Hallam writes: "While there are many reasons why size economies may be important, three broad areas of concern seem particularly relevant. The first issue deals with the interaction of size economies, perfect competition and welfare economics: If the long run average cost (LAC) curve for a farm is downward slopping in the relevant region, then long run marginal cost curve (LMC) will lie below it and competitive marginal pricing will not prevail. This could lead to monopolization of the industry and the associated problems with obtaining a competitive and welfare maximizing equilibrium. Second, while most economists tend to be concerned about size economies only as they affect efficiency and the sustainability of competitive equilibrium, much research in American agriculture has focused on the farm size as an independent issue. This interest is based on the normative desirability of the family farm. Third, economies of scale are one of the factors that affect the growth path of the industry. Over time industries adapt to meet changes in technology, consumer preferences and world conditions. By understanding

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[12] Debertin, D.L., "Agricultural Production Economics," Macmillan Publishing Company, New York, 1986, p. 154.

[13] Kislev, Yoav and Willis Peterson, "Economies of Scale in Agriculture: New Evidence," Sept. 1990, (Mimeographed).

why and which firms grow, investors can make wise decisions on how to allocate societies' resources in an uncertain world."[14] pp. 65-66.

Khan M.H., writes, "In many countries where government policies of subsidizing agriculture favor large land owners, the effect of increasing returns on the land provides a strong incentive to acquire land from small farmers who cannot compete in obtaining the necessary inputs."[15] p. 126. As may be noticed what Khan is referring to is the monopolization by one industry -- the implication drawn by Hallam while he was raising the first issue.

Now one may ask what if small farms are relatively efficient, then how would that interest us in studying the productivity relationship. But it turns out that in agriculture, particularly in less developed countries, this question has occupied agricultural economists more than anything else for the special reason that such relationship has implications for policy issues like land ceilings and land redistribution.[16] In the same vein of thought Alain de Janvry writes, "Establishing the conditions under which an inverse relation between land productivity and farm size may exist is essential to identify the conditions for potentially successful redistributive land reforms."[17] p. 2.

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[14] Hallam A, op cit., it may be pointed out that while Hallam used the term size and scale interchangeably, his reference is to 'Returns to Scale.'

[15] Khan, M.H., "The Economics of the Green Revolution in Pakistan," Praeger Publishers, New York, 1975.

[16] See, Bardhan, P.K., op cit., p. 1371, Bhagwati, J. and Chakravarty, S., "Contributions To Indian Economic Analysis: A Survey," American Economic Review, 59, No 2, Suppl., Sept. 1969, p. 30-43.

[17] Alain de Janvry, "Land Ownership and Economic Development," paper presented at the seminar on Land Market and Land Prices: Performance and Forms of Intervention, Universidad International, Menendz Pelayo, Spain, Sept. 24-26, 1986, (Mimeographed).

Bruce Hall and Phillip LeVeen had, however, a totally different reason to be interested in size productivity relationships.[18] Thus, they write, "If farm size policies restrict farm size to the declining portion of the long run average cost curve, they will impose a loss to the economy. What the severity of that loss will be and how policies might moderate it cannot be known without examining the sources of inefficiency associated with decreased size." p. 590.

3) **Evidence on scale economies and explanations:**

The available evidence on scale economies as found with regard to agriculture, irrespective of the level and aggregation of studies, is mixed. The same is though not true, fortunately, about the explanations advanced. Few major arguments prevail. Thus, where increasing returns to scale have been evidenced, the indivisibility of modern technology, composed of biological-mechanical components, is advanced. Where decreasing returns to scale have been found, high input use, particularly that of labor per unit of land, soil quality and management difficulties of larger units have been pointed out as the answer.

Thus, while explaining increasing returns to scale in advanced agriculture, like that of USA, Ruttan says, "We interpret these results as reflecting the rapid, though incomplete, introduction and adoption of mechanical technology in the developed economies. These mechanical technologies tend to require somewhat lumpy or discrete adjustments in factor-

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[18] Bruce Hall and Phillip LeVeen, "Farm Size and Economic Efficiency: The Case of California," Amer. J. Agr. Econ., Nov 1978.

factor ratios at the farm level."[19] p. 50. Ruttan's explanation has been used by Ijaz Nabi et al. in their attempts to explain increasing returns to scale in some regions of Pakistan's agriculture.[20]

The argument of Khan, who found increasing to scale for some regions of Pakistan, falls similarly in the same category when he writes that large farms are more productive because of this greater use of "non-traditional"[21] inputs.

While Ruttan's explanations have been enriched by Lau and Yotopoulos findings,[22] Kislev and Peterson do not see such explanations well-founded both in their dynamic and static versions. Thus they write, "It is hard to find long-run indivisibilities on the farm. Returns to scale is a long run concept and in the long run size distributions of machinery, land, structures, irrigation systems, herds, and flocks are continuous, not lumpy. Tractors and their implements come in a variety of sizes, other machines also come in a variety of sizes. In the few cases where large machines are the most

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[19] Ruttan, V.W., Scale, Size, Technology and Structure: A Personal Perspective, (in) Robison, L.J., "Determinants of Farm Size and Structure," Michigan Agricultural Experiment Station, Journal Article No. 12899, 1988. Also see his work with Hayami Yujiro, i.e., Hayami, Y. and Ruttan, V.W. "Agricultural Development: An International Perspective," The Johns Hopkins Univ. Press, Baltimore 1985, p. 147.

[20] Ijaz Nabi, et al., "The Agrarian Economy of Pakistan," Oxford Univ. Press, Karachi, 1984.

[21] By "non-traditional" Khan means inputs like fertilizer, hired labor and farm machinery, p. 76, "Farm Size, and Land Productivity Relationships in Pakistan," Pakistan Development Review, Vol XVIII, No 1, 1979.

[22] Lau, L. J. and Pan A. Yotopoulos, "The Meta-Production Function Approach to Technological Change in World Agriculture," Dept. of Economics and Food Research Institute, Stanford Univ., March 1987. Lau and Yotopoulos found that returns to scale are positively related to levels of machinery input per farm.

efficient, rental markets develop. Small farmers also, then, have the option of purchasing lower cost, used machines." p. 3.

Regarding the dynamic version[23] of the increasing returns to scale hypothesis, Kislev and Peterson write, "that it is not consistent with the continuing prevalence of part-time farming nor is this hypothesis consistent with the observed cessation of the growth in farm size which occurred from the mid 1970's to the early 1980's without a corresponding halt to the progression of new technology." p. 4.

Coming to the other major line of argument that relates to justifying decreasing returns to scale, the main contention is that the small farms use more inputs, especially labor, per unit of land and hence manage to excel large farms in land efficiency.

Observers of developing economies have provided explanations for the higher input of labor in terms of lower supply price of family labor in small farms compared to the large ones.[24] These explanations assume the non-existence of outside opportunities for family labor. A related hypothesis in this regard is that the quality of labor on large farms is inferior compared to the one on small farms, and that the hazards of supervision are also there.[25] Yet another explanation in respect of the prevalence of decreasing

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[23] Kislev, Y. and Peterson, Willis, op cit.

[24] See, i) Sen, A., "An Aspect of Indian Agriculture," The Economic Weekly Annual Numbers, Feb. 1962. ii) Sen, A., "Size of Holding and Productivity," Economic Weekly Annual Numbers, Feb. 1964. iii) Mazumdar, D., "On the Economics of Relative Efficiency of Small Farmers," the Economic Weekly, Special Number, July 1963.

[25] See Bardhan, P., "Size, Productivity and Returns to Scale: An Analysis of Farm Level Data in Indian Agriculture," Journal of Political Economy, Vol 81, No 6, Nov/Dec 1973, for the contention that the quality of hired and owned family labor might be different, p. 1381.

returns to scale has been in terms of the quality of land. According to this point of view the smaller farms have a higher percentage of acres under irrigation, which operates as a source of efficiency on small farms.[26]

Methodology

1) **Data:**

The data utilized in this study were collected by way of field survey conducted in May-June 1988. The sample size which was then decided in advance according to the available statistics, about the number of farms, distribution of farms in various farm size classes, tenurial status, operated holding and irrigation status, had to be revised in view of existing field conditions. Especially medium and large farms had to be found. Total farms in the sample equals 60.

2) **Econometric analysis:**

a) **Functional form:**

The Cobb-Douglas production function was utilized to estimate production elasticities and to measure returns to scale. The formulation, before taking logs, is:

$$Q_i = A\, X_{1i}^{\delta_1}\, X_{2i}^{\delta_2}\, X_{3i}^{\delta_3}\, X_{4i}^{\delta_4}\, e^{U_i}$$

P.J. Lloyed has traced the use of production function in studying efficiency to Von Thunen; the 18th century German agriculturalist in his

[26] Khusro, A.M., "The Economics of Land Reforms and Farm Size in India," Macmillan Company of India Limited, Delhi, 1973, pp. 117-123.

paper, "Elementary Geometric and Arithmetic Series and Early Production Theory."[27] Heady & Dillon, however, have credited Justus von Liebig as the first economist to define such a fundamental relationship and Mitscherlich and Spillman to use it.[28] Still, however, it was not until the appearance of Cobb and Douglas' paper "A Theory of Production" that the estimation of production functions became common-place in economics.[29] About the indiscriminate use of production functions Harald Jensen writes, given the problems of specification bias, intercorrelations among inputs categories, and problems growing out of aggregating inputs and outputs, it is questionable whether aggregate production function analysis should play any role beyond that of a diagnostic technique in the preliminary stages of analysis (i.e., for suggesting possible resource malallocations.) p. 46.[30] The way the Cobb-Douglas production function is employed, however, varies depending on the availability of data, and kind of restrictions one is willing to impose on the functional form and the nature of assumptions one makes with respect to factor and product markets, and the profit maximization.[31]

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[27] Journal of Political Economy, Vol. 77, No. 1, Jan/Feb 1969.

[28] See Heady & Dillon, "Agricultural Production Functions," Iowa State University Press, Ames, Iowa, 1961, pp. 10-11.

[29] See Chambers, R.G., "Applied Production Analysis: A Dual Approach," Cambridge Univ. Press, New York, 1988, p. 3.

[30] Farm Management and Production Economics, in Martin Lee (ed), "A Survey of Agricultural Economics Literature," Vol. 1, University of Minnesota Press, 1977.

[31] For the different ways to estimate Cobb-Douglas production function, besides Michael D. Intriligator, "Econometric Models, Techniques and Applications," Prentice-Hall, Englewood Cliffs, NJ, 1987, pp. 262-280. See Wallis, K.F., "Topics in Applied Econometrics," University of Minnesota Press, 1980, pp. 50-80.

b) **Estimation:**

The ordinary least squares technique was used to obtain parameter estimates, using

$$\ln Q_i = a + \sum_{i=1}^{4} \delta_i \ln X_{ij} + U_i \qquad i = 1..4,\ j = 1..60$$

where U_i is the disturbance term, Q_i, the value of output, X_{ij} the explanatory variables and 'a', δ_i the parameters to be estimated. The parameter "a" is the log of A.

It is assumed here that the parameters a and δ_i's and the prices are the same for all farms. The differences among farms are summarized by the disturbance term U_i. These differences could relate to the farms knowledge, skill, location advantages, luck, effort, etc.

This study has attempted to use the procedure of <u>directly</u> estimating the parameters 'a' and 'δ_i' because it does not make any assumptions with regards to returns to scale or profit maximization. Estimation of production parameters this way has been criticized for the problems of simultaneity, multi-collinearity and heteroskedesticity.[32] Particularly, however, the criticism of simultaneity may not be warranted in agriculture when output lags input decisions.

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[32] Intriligator, M.D., op cit., p. 267. To circumvent these problems Intriligator has discussed four other estimation procedures viz; i) Estimation in intensive form, relating output per worker to the capital labor ratio, with the assumption that constant returns to scale prevails. ii) Estimation based on factor shares, assuming constant returns to scale perfect competition and profit maximization. iii) The classical approach using the marginal productivity relations and assuming perfect competition and profit maximization. iv) Estimating the simultaneous system consisting of the production function and the first order conditions for profit maximization.

Regarding the other problems viz, multi-collinearity and heteroskedesticity, these were diagnosed and taken care of using the appropriate techniques. In fact, only heteroskedesticity was found[33] to be a problem. Hence heteroskedesticity-free estimates were obtained using the White procedure.

To test for structural differences among the small, medium and large sized farms, the test discussed in Weisberg[34] and Dudley Wallace and Silver Lew[35] was used. While there are slight differences between Weisberg and Wallace-Silver's form of the test, these relate to matters of detail and not substance.

3) **Description of Variables:**

The following variables were included in the final analysis.

- human labor adjusted for off-farm work,
- land,
- bullock labor,
- machinery, and
- gross value of crop output.

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[33] By way of residual analysis and using the testing procedure suggested by Goldfeld and Quant. Alternative ways, in this regard, have been suggested by i) Breusch-Pagan, ii) Cook and Weisberg, iii) Ramsey, iv) Glejser. While the Goldfeld-Quant test is limited to considering only one variable at a time, the Cook and Weisberg test is general handling more than one variable simultaneously. For a discussion of the other tests see, Maddala, G., "Introduction to Econometrics," Macmillan Publishing Co., 1988, pp. 162-167.

[34] Weisberg, S., "Applied Linear Regression," John Wiley and Sons, New York, 1985, pp. 179-183.

[35] Wallace, D., and Silver, L., "Econometrics: An Introduction," Addison-Wesley Publishing Company, New York, 1988, pp. 239-242.

Variables such as fertilizer, farm yard manure, insecticides, irrigation charges could not be included for the following reasons: i) Some of these variables were found to be collinear with other variables. ii) Complete data on some of the variables could not be generated (e.g. insecticides). In fact, very few farm applied insecticides. iii) Data on irrigation water was not gathered at all as all the farms included in the sample are irrigated. But this, however, does not mean that these sample farms are strictly the same in this respect. A proper consideration of this variable would have involved adjusting for quality differences of irrigation water, i.e. its timely availability, amount and cost of management. The included variables are described as below:

a) **Human labor:**

This is measured in labor days per farm. This includes hired labor, net labor exchanged and family labor, unadjusted for quality. Market wage that prevailed at the time of the survey ranged from Rs.30-Rs.40 per day (Rs.23 equal one dollar) depending on whether food is served or not.

b) **Land:**

Refers to cropped acres per farm in acres, unadjusted for quality. This measure may be source of bias, in one sense; to the extent cropping intensity is significantly larger on small farms than the large farms, the average farm size for the small farms would be overestimated. Annual rent per acre, at the time of the survey, varied between Rs.1000-Rs.2000 per acre depending on the quality of land.

c) **Bullock labor:**

Measured in days per farm per year, bullock labor, like that of human labor, includes labor hired, owned or net exchanged. Hired bullock services are becoming common in the study area, while exchange bullock labor still prevails. In view of the availability of tractor services, it has been observed that bullock ownership has been on the decline. Farmers seem to have realized the higher cost of keeping bullocks. That is, the machinery services, particularly that of tractor, are available not only on economical rates but the land area, that would otherwise be allocated to fodder, has been released now for crop growing. The importance of this factor is easily realized once the nature of small operational land holding in NWFP in general and the valley in particular is considered. Daily charges for a pair of hired bullock service was Rs.60, when the field survey was conducted.

d) **Farm machinery:**

Measured in hours per farm, again such machinery services as tractor for ploughing and thresher for threshing are now quite common. Only where bullock services becomes totally indispensable, tractor services are not used. One factor constraining even further use of such machine services may be that other specialized machinery suited to the farming conditions in the valley has yet not been available. Machinery services, referring to tractors and threshers could be obtained at Rs.55 per hour. While thresher services are available at the rate of 1 maund per 10 maunds threshed irrespective of crop, the cost comes to the same as Rs.55 per hour.

e) **Gross value of crop output:**

Gross farm output was obtained by aggregating over different crops and fruit produced and multiplied by respective crop prices before aggregation.

To the extent small and large farms grow relatively different amounts of valuable crops, i.e. vegetables, tobacco and fruit specification bias, particularly with regards to returns to scale would arise. This may be referred to as crop composition effect across farm size categories in the same region.

- III -

ANALYSIS

With a view to estimate marginal productivities, returns to scale and test for structural differences across different farm size categories, three different regression models were fitted. To keep track of things these models have been distinguished as Model I, II and III. The general form of the regression model is, however, the same; viz; the Cobb-Douglas in its multiplicative form as given below:

$$Q_i = A\, X_{1i}^{\delta_1}\, X_{2i}^{\delta_2}\, X_{3i}^{\delta_3}\, X_{4i}^{\delta_4}\, e^{U_i}$$

This is the multiplicative Cobb-Douglas production function, where

X_{1i} - Human labor, adjusted for off-farm work

X_{2i} - Bullock labor

X_{3i} - Farm machinery

X_{4i} - Cropped area; and

U_i - Stochastic disturbance term

A, δ's are parameters to be estimated. In its present form the Cobb-Douglas function is non-linear in variables. To apply ordinary least squares it can be appropriately estimated only if all the variables are transformed in log linear form. Taking logarithms to the natural base, we obtain,

$$\ln Q_i = a + \delta_1 \ln X_{1i} + \delta_2 \ln X_{2i} + \delta_3 \ln X_{3i} + \delta_4 \ln X_{4i} + U_i$$

or

$$\ln Q = a + \sum_{i=1}^{4} \delta_i \ln X_i + U_i$$

where a = ln A; A can be recovered back after estimation as A=antilog a.

1. **Marginal Productivies and Resource Efficiency - Model I:**

a) **Estimation:**

Model I was fitted to yield an estimate of the production elasticity for each input.[36] The functional form of the model fitted, in its logarithmic form, is given as:

$$\ln Q_i = a + \sum_{i=1}^{4} \delta_i \ln X_i + U_i$$

The parameter estimates were obtained using OLS. After estimation, diagnostics tests were performed to check for any violations of the assumptions,[37] underlying the OLS technique.

b) **Diagnostics:**

After fitting the model, diagnostic tests were performed to check for multicollinearity and hetroskedesticity. Since the data used in fitting the model is cross-section, the problem of autocorrelation was not suspected on a priori grounds.[38]

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[36] In the simple case of production function where output is regressed against a single input, production elasticity and returns to scale would be synonymous. In practice, however, production requires two or more inputs.

[37] These are i) no multicollinearity, ii) $E(U_i^2)=\delta^2$, iii) $E(U_iU_j)=0$ $i \neq j$; and that the assumption of normality holds.

[38] See Doran, Howard, "Applied Regression Analysis in Econometrics," Marcel and Dekkar Inc., 1989, on this. He writes, "This assumption (i.e., $E(U_i\ U_j) = 0$ when $j \neq i$) is usually perfectly reasonable when dealing with cross-sectional data. When dealing with time series data, however, the assumption is not nearly as plausible. pp. 192-193. Also see Wallis, K.F., "Topics in Applied Econometrics," Univ. of Minnesota Press, Minneapolis, 1980, p. 57, for a slightly different opinion.

i) To test for multicollinearity, the correlation matrix between the variables, dependent as well as the independent, was first of all examined. It was found that the land variable may be collinear with the labor variable. To verify if such a problem in fact exists, alternative tests were performed. These included the computation of variance inflation factors (VIF's) and condition number on the basis of this information, thus, obtained moderate multicollinearity was diagnosed.[39]

A brief summary of the diagnostics is presented in Table III.1.

Table III.1: Multicollinearity Diagnostics

1. Condition Number (k)*: 9.17
2. Correlation Matrix:

	Output	Labor	Bullock	Machinery	Land
Output	1	.	.	.	.
Labor	0.95	1	.	.	.
Bullock	0.93	0.88	1	.	.
Machinery	0.75	0.72	0.55	1	.
Land	0.89	0.91	0.88	0.65	1

3. VIF's**

	17.27	8.89	4.22	14.97

* Condition Number (k) = $(\lambda \max / \lambda \min)^{1/2}$, where λ max and λ min are, respectively the largest and smallest eigen values.

** Variance Inflation Factor (VIF's) = $(1/1 - R_i^2)$ where R_i^2 is the squared multiple correlation coefficient obtained from the regression of X_i, one of the independent variables, on the rest of the explanatory variables.

[39] The convention is that if the value of the condition number lies between 10 and 30, then multicollinearity is moderate. See Gujarati, D.N., "Basic Econometrics," McGraw-Hill Publishing Co., 1988, p. 301.

ii) To test for hetroskesdesticity, residual plots were obtained and studied. These indicated that the land variable might be the source of heteroskedesticity. This problem was, however, later on confirmed through the Goldfeld-Quant test.[40]

To correct for heteroskedesticity the 'White' procedure was used. Both the OLS and White corrected regression results are presented in Table III.2.

c) Plausibility of the estimates:

Regarding the significance of the OLS estimates, the estimated parameters for all other explanatory variables are significant at 1% excepting the estimated land parameter which is significant at 5% level of significance. The White-corrected parameter estimates are, however,

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[40] This test involves the calculation of two least-squares regression lines, one using data thought to be associated with low variance errors and the other using data thought to be associated with high variance errors. If the residual variances associated with each regression line are approximately equal the homoskedesticity assumption viz; $E(U_i)^2=\delta^2$ cannot be rejected. To implement this test, the procedure is to i) order the data by the magnitude of the independent variable X_i, which is thought to be related to the error variance. ii) omit the middle 'd' observations. The selection of 'd' is, however, arbitrary. The standard practice is to set the value of 'd' to $1/5^{th}$ of the sample size. iii) fit two regressions and obtain error sum of squares in each case viz; ESS_1 and ESS_2. iv) construct F-test such that: $F = ESS_1/ESS_2$ distributed with N-d-2K/2 degrees of freedom both in the numerator as well as denominator. Here K= the number of estimated parameters, including the constant term. v) small values of computed F compared with critical values of F taken from the F-dist at some prechosen significance level leads to the acceptance of the null hypothesis of constant variance or homoskedesticity.

On the other hand, if the residual variances differ across the two data then F will be large relative to the critical F appropriately chosen, and the hypothesis of 'equal variance' will be untenable. See Pindych, R.S. and Rubinfeld, D.L., "Econometric Models and Economic Forecasts," McGraw-Hill Co., New York, 1981, pp. 148-149.

significant for all the explanatory variables including land at 1% level of significance.

The signs of the estimated coefficient are positive as expected both in the case of OLS and White-corrected results.[41] Since all variables were expressed in logarithms, the estimated parameters are easily interpreted, i.e., the estimated parameters are production elasticities with respect to the individual inputs.[42]

d) Marginal Productivities of Resource Inputs:

Based on the estimated regression equation, viz;

$\ln Q_i = 3.25.975 + 0.252\ln X_1 + 0.331\ln X_2 + 0.240\ln X_3 + 0.167\ln X_4$

$\bar{R}^2 = 0.975$

$F\ (4,55) = 542.97$

The estimated marginal productivities may be seen from Table III.3. In the case of log linear Cobb-Douglas production function, the marginal productivities of individual resource inputs are given as:

$$MPP_{Xi} = \delta \ln Q_i \ / \ \delta_{Xi} = \delta_i \quad Q_i \ / \ X_i$$

where δ_i is the elasticity of production with respect to input X_i and Q/X_i in the average product of X_i.[43] Since the dependent variable $\ln Q_i$

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[41] It may be pointed out that the White procedure has to do more with the correction of parameters' standard errors than the values of the coefficients themselves. Thus, in a sense, such comparison between the OLS and White-corrected parameter estimates would be redundant.

[42] That is, $\delta_i = \epsilon_i = \partial \ln Q_i \ / \ \partial \ln X_i$
$= \partial Q_i \ / \ \partial X_i \ . \ X_i \ / \ Q_i = MPP_{Xi} \ . \ 1 \ / \ APP_{Xi}$

[43] This can be demonstrated as: $\epsilon_i = \partial \ln Q_i \ / \ \partial \ln X_i = \partial Q_i \ / \ \partial X_i \ . \ X_i \ / \ Q_i$
$= \partial Q_i \ / \ \partial X_i = \epsilon_i \ . Q_i \ / \ X_i$
$= \epsilon_i \ . \ APP_{Xi}$

was expressed in value terms in this study, the estimated marginal products are at the same time value of marginal products.

Table III.2: Regression Estimates of the Cobb-Douglas Production Function Fitted to the Cross-Section Survey Data: 1987-88

Dependent variable: (LnQ_i) Gross Value of Crop Output (Rs per farm per annum)

Estimated Values of:	Explanatory Variables				
	Labor	Bullock	Machinery	Land	Constant
0	1	2	3	4	5
Coefficients (δ_i)	0.252	0.331	0.240	0.167	5.787
OLS Std. errors	0.091	0.047	0.040	0.093	0.421
OLS t-values	2.769	7.043	6.000	1.795	13.746
P-values	0.007	0.000	0.000	0.079	0.000
White Corrected Std. errors	0.080	0.047	0.036	0.065	0.293
White t-values	3.15	7.043	6.666	2.569	10.750
P-values	0.002	0.000	0.000	0.012	0.000
Intercept term in real units	--	--	--	--	325.975
$\Sigma\ \delta_i$	0.991397				
R^2	0.97530				
$\bar{R}^2$	0.97531				
F(4,55)	542.96829				
White-Corrected Var-Cov matrix of Est. Parameters:					
(X_1) Labor	0.006339	-0.002786	-0.001899	-0.002283	-0.020610
(X_2) Bullock	--	0.002253	0.001257	-0.000620	0.005530
(X_3) Machinery	--	--	0.001309	-0.000410	0.003601
(X_4) Land	--	--	--	0.004174	0.012391
Constant	--	--	--	--	0.085932

e) **Resource Efficiency:**

For production under given technology environment with both output and input variable, the ideal measure of the efficiency of resource use is provided by the marginal return to opportunity cost ratios of the various resources. Concomitantly these ratios indicate the direction of

changes that should be made in resource allocation if profits are to be maximized.[44]

Of course, this is the famous microeconomic proposition for resource allocation couched in different terms. Following this proposition, the marginal return to opportunity cost ratios of various resource inputs may be seen from Column 4 in Table III.3.

Thus as may be seen except for the land resource input all the other inputs, contributed over and above what it costed to use them. The land variables, however, could recover 80% of the cost.

Considering the efficiency indices for the various inputs, it seems that there is still more scope for additional usage of machinery inputs.

Table III.3: Estimated Value of Marginal Products* (evaluated at the means) of the Different Items of Resource Input

Item of Resource Input	Unit	Value of Marginal Products $(VMP)_{Rs}$	Resource Opportunity Cost (Rs)/unit	VMP to Opp. Cost Ratio
0	1	2	3	4
1. Human labor	days	46.40	30	1.55:1
2. Animal labor	days	55.77	50	1.12:1
3. Machinery	hrs	278.12	50	5.56:1
4. Land	acres	926.64	1150	0.81:1

*Since output was expressed in value terms, the estimated marginal products are at the same as value of marginal products.

[44] Heady, E.O., and John Dillon, "Agricultural Production Functions," Iowa State Univ. Press, Ames, Iowa, 1961, p. 633.

2. Returns to Scale - Model II

a) Specification:

The following regression equation was fitted to the sample data to obtain an estimate of the returns to scale.

$$\ln Q_i = B_0 + B_1 \ln X_{1j}/X_{4j} + B_2 \ln X_{2i}/X_{4j} + B_3 \ln X_{3j}/X_{4j} + B_4 \ln X_{4j} + U_i$$

As may be observed, this equation is structurally different from the regression equation employed in Model I. The variables X_{1j}, X_{2j}, X_{3j} have been expressed, in this case, in per acre units.[45]

Also while using this approach to obtain the estimate of the returns to scale parameter one should be careful 'not' to express the dependent variable $\ln Q_i$ and independent variable land, $\ln X_{4i}$, in per acre units because doing that would constrain the regression equation to constant returns to scale and there would be no sense to test for returns to scale.[46]

Furthermore, the return to scale estimate in Model I is obtained by way of summing the coefficients on individual inputs, while in this case the deviation of the coefficient of land variable i.e., X_{4j}, from unity can be tested to yield a measure of the returns to scale.[47]

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[45] Or efficiency units as usually called.

[46] This point is fully discussed in Sahota, G., "Efficiency of Resource Allocation in Indian Agriculture," American Journal of Agri. Economics, Vol 50, No 3, Aug. 1968, p. 585.

[47] See Bardhan, P.K., "Size, Productivity and Returns to Scale: An Analysis of Farm-Level Data in Indian Agriculture," Journal of Political Economy, Vol 81, No 6, Nov/Dec 1973, p. 1375-76.

Computationally, this method offers the easy way to statistically test returns to scale when more than two independent variables are involved in the regression.[48]

b) **Estimation:**

The estimated regression equation is as follows:

$$\ln \hat{Q}_i = \underset{(19.751)}{5.787} + \underset{(3.15)}{0.252} \ln X_1 + \underset{(7.043)}{.331} \ln X_2 + \underset{(6.67)}{.240} \ln X_3 + \underset{(41.29)}{.991} \ln X_4$$

The following hypothesis was tested:

$NH = \hat{B}_4 = 1$
$AH = NH$ is false

with $\hat{B}_4 = 0.991$ and associated standard error of 0.024, $t^* = \frac{0.991-1}{0.024} = 0.375$

Both at 1% and 5% level of significance the null hypothesis of constant returns to scale could not be rejected.

Detailed regression results of the estimated equation may be seen from Table III.4.

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[48] To appreciate this point, see i) Rao, P. and LeRoy R. Miller, "Applied Econometrics," Wadsworth Publishing Co., Inc., Belmont, California 1971, pp: 138-139. Rao and Miller show that to test the hypothesis $NH = 1 = C_1B_1 + C_2B_2 + \ldots$, against $AH = NH$ is false, one needs to obtain $v(d) = C_1^2 \text{ var } (\delta_1^2) + C_2^2 \text{ var } (\delta_2^2) + \ldots + 2\, C_1C_2 \text{ Cov } (\delta_1, \delta_2) + \ldots$ where 'd' is the test statistic designed as $d = C_1\hat{\delta}_1 + C_2\hat{\delta}_2 + \ldots$ and Cov stands for covariance between the estimates $\hat{\delta}_1$ and $\hat{\delta}_2$. ii) Johnston, "Econometric Methods," McGraw-Hill Book Co., 1984. Johnston has discussed the following test statistic that can be used to test returns to scale:

$$F = \frac{(R\hat{B} - r)' \, [R\,(X'X)^{-1} R']^{-1} \, (R\hat{B} - r)}{q\,\hat{\delta}^2} \sim F(Q, n-k) \text{ df.}$$

Table III.4: Statistical Results of the Regression Equation Measuring Returns to Scale

Dependent variable: (LnQ_i) Gross Value of Crop Output (Rs per farm per annum)

Estimated Values of:	Explanatory Variables				
	Labor	Bullock	Machinery	Land	Constant
0	1	2	3	4	5
Coefficients (β_i)	.252	.331	.240	.991	5.787
OLS Std. errors	.091	.047	.040	.026	0.421
OLS t-values	2.769	7.043	6.000	38.12	13.746
P-values	.007	.000	0.000	0.000	0.000
White Corrected Std. errors	.080	0.047	0.036	.024	.293
t-values	3.15	7.043	6.666	41.292	19.751
P-values	0.003	0.000	0.000	0.000	0.000
Intercept term in real units	--	--	--	--	325.975
R^2	0.975				
$\bar{R}^2$	0.974				
F(4,55)	542.96829				
White-Corrected Var-Cov matrix of Est. Parameters:					
(X_1) Labor	0.0006339	--	--	--	--
(X_2) Bullock	-0.002786	0.002253	--	--	--
(X_3) Machinery	-0.001899	0.001257	0.001309	--	--
(X_4) Land	-0.000629	0.000105	0.000258	0.000595	--
Constant	-0.020610	0.005530	0.003601	0.000913	0.085932

3. Testing for Structural Differences Between Farm Size Categories - Model III

a) Specification:

Model III was constructed to test for structural differences across different farm size categories. The point here is to seek answers to the following questions: Are we going to lose any information if all data for farms are pooled into one data set? Alternatively, should we fit different models to the data for the different farm size categories separately as they are structurally different entities.

Stated yet in another way this test verifies whether farms belonging to different categories of farm operate on the same production function or not.

The typical procedure[49] for testing for structural differences is to construct an F test on the assumption that the parameters do not change and the usual assumptions of OLS are met. To obtain the ingredients of the test, the following four regression equations were fitted.

$$\ln Q_i = a + \sum_{i=1}^{4} \alpha_i \ln X_{ij} + U_i \qquad \text{Eq. 1}$$

$$\ln Q_i = \gamma_{01} D_1 + \gamma_{02} D_2 + \gamma_{02} D_3 + \sum_{i=1}^{4} \alpha_i \ln X_{ij} + U_i \qquad \text{Eq. 2}$$

where D_1 = 1 if farm size category is (12.5 - 25.5) acres
0 otherwise

D_2 = 1 if farm size category is (25.5 and above) acres
0 otherwise

D_3 = 1 if farm size category is (12.5 and less) acres
0 otherwise

$$\ln Q_i = a + \gamma_{11} Z_1 + \gamma_{12} Z_2 + \gamma_{13} Z_3 + \gamma_{21} W_1 + \gamma_{22} W_2 + \gamma_{23} W_3 + \gamma_{31} V_1 + \gamma_{32} V_2 + \gamma_{33} V_3 + \gamma_{41} Y_1 + \gamma_{42} Y_2 + \gamma_{43} Y_3 + U_i \qquad \text{Eq. 3}$$

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[49] For this procedure see S. Weisberg, "Applied Linear Regression," John Wiley and Sons, New York, 1985, pp. 179-183 and Wallace, D. and Silver, L., "Econometrics: An Introduction," Addison Wesley, New York, 1988, p. 239-40.

where

$Z_1 = D_1X_{1j}$, $W_1 = D_1X_{2j}$, $V_1 = D_1X_{3j}$, $Y_1 = D_1X_{4j}$

$Z_2 = D_2X_{1j}$, $W_2 = D_2X_{2j}$, $V_2 = D_2X_{3j}$, $Y_2 = D_2X_{4j}$

$Z_3 = D_3X_{1j}$, $W_3 = D_3X_{2j}$, $V_3 = D_3X_{3j}$, $Y_3 = D_3X_{4j}$

$$\begin{aligned} \ln Q_i = \gamma_{01}D_1 + \gamma_{02}D_2 + \gamma_{03}D_3 + \gamma_{11}Z_1 + \gamma_{12}Z_2 + \gamma_{13}Z_3 + \\ \gamma_{21}W_1 + \gamma_{22}W_2 + \gamma_{23}W_3 + \\ \gamma_{31}V_1 + \gamma_{32}V_2 + \gamma_{33}V_3 + \\ \gamma_{41}Y_1 + \gamma_{42}Y_2 + \gamma_{43}Y_3 + U_i \end{aligned} \qquad \text{Eq. 4}$$

The intercept term has been suppressed in Eq. 2 and 4 to avoid the 'dummy trap', i.e. perfect multi-collinearity.[50]

b) **Estimation:**

The estimated regressions corresponding to the four equations have been summarized in Table III.5.

[50] See Wallace, D. and Silver, L., op cit., p. 210-217 for different reparameterization of regression equations involving the use of dummy variables.

Table III.5: Regression Results Used To Obtain The Ingredients For Testing Structural Differences Between Farm Size Categories

Variable	Parameter Estimates of Equation No: 1	2	3	4
Intercept	5.79 (17.74)*	--	5.22 (7.89)	--
X_1	0.25 (3.17)	0.35 (2.46)	--	--
X_2	0.33 (6.98)	0.28 (3.95)	--	--
X_3	0.24 (6.65)	0.21 (4.01)	--	--
X_4	0.17 (2.59)	0.18 (1.94)	--	--
D_1	--	5.34 (12.20)	--	6.97 (10.28)
D_2	--	5.44 (14.76)	--	4.90 (5.40)
D_3	--	5.45 (12.78)	--	4.64 (4.74)
$Z_1 = D_1X_1$	--	--	0.45 (2.81)	0.44 (1.39)
$Z_2 = D_2X_1$	--	--	0.38 (3.72)	0.42 (2.94)
$Z_3 = D_3X_1$	--	--	0.41 (1.76)	0.54 (2.94)
$W_1 = D_1X_2$	--	--	0.18 (2.11)	0.18 (2.37)
$W_2 = D_2X_2$	--	--	0.46 (9.96)	0.45 (7.88)
$W_3 = D_3X_2$	--	--	0.18 (1.07)	0.17 (1.04)
$V_1 = D_1X_3$	--	--	0.02 (0.24)	0.03 (0.52)
$V_2 = D_2X_3$	--	--	0.16 (4.97)	0.16 (4.59)
$V_3 = D_3X_3$	--	--	0.24 (1.84)	0.25 (2.11)
$Y_1 = D_1X_4$	--	--	0.41 (2.12)	0.46 (3.02)
$Y_2 = D_2X_4$	--	--	-0.14 (-1.06)	-0.11 (-0.90)
$Y_3 = D_3X_4$	--	--	0.29 (1.07)	0.07 (0.19)
RSS**	1.361090	1.246752	0.977454	0.944499
df***	55	53	47	45

* Figures in the parentheses are the associated t-values.
** Residual sum of squares
*** Degrees of freedom.

c) **Testing procedure and plausibility of estimates:**

Tests concerning the slopes and intercepts of different regression lines use the general model represented by equation 4 as the alternative model. The F-test, for testing the adequacy of models represented by Equation 1, 2 and 3, is given by:

$$F_i = \frac{(RSS_i - RSS_4) / (df_i - df_4)}{RSS_4/df_4} \qquad i = 1,2,3$$

where F_i is the F-statistic associated with i=1,2,3, with $df_i - df_4$ degrees of freedom in the numerator and df_4 degrees of freedom in the denominator. RSS_4 and RSS_i are respectively the residual sum of squares corresponding to equation 4 and i=1,2,3.

If the model is inadequate when compared to the general model represented by Equation 4, then F_i will be large when compared to a critical F value taken from F table at some prechosen level of significance.

Based on the formula for F_i, the values of F corresponding to Equation 1, 2 and 3, along with P-values are as follows:

F_i	$F_i = \frac{(RSS_i - RSS_4) / (df_i - df_4)}{RSS_4/df_4}$	P-value
F_1	1.985	$F(10,45,1.985) = 0.057882 \approx 0.06$
F_2	1.800	$F(8,45,1.800) = 0.102171 \approx 0.10$
F_3	0.785	$F(2,45,0.785) = 0.462265 \approx 0.46$

The following hypotheses were tested:

NH_1 - Equation is as adequate as Equation 4

AH - Only Equation 4 is adequate.

NH_2 - Equation 2 is as adequate as Equation 4.

AH - Only Equation 4 is adequate.

NH_3 - Equation 3 is as adequate as Equation 4.

AH - Only Equation 4 is adequate.

As evident from the P-values, none of null hypotheses could be rejected at 1% and 5% level of significance. This means that we would not loose important information if all the farms are grouped into one data set. That is, no structural differences exist between them.

However, Equations 1 and 2 would be inadequate, respectively at 6% and 10% level of significance -- meaning that farms in different farm size categories might be operating on separate production functions. Given the estimates for intercept dummies in Equation 2, Table III.5, this means that the small farms operate on a production function with a higher intercept than the medium and large farms.

- IV -

CONCLUSIONS

Subject to the quality of data, the estimation techniques and the stochastic nature of parameter estimates, the main findings of this study are as follows:

Resource Use and Efficiency

With the exception of the land resource input the value of marginal products (VMP's) of the rest of the inputs, namely, human and animal labor, and machinery, exceed their prices. This points to reorganization with regards to these inputs. Particularly, additional hours of machinery would be rewarding as the VMP to price ratio for this input is 5.56:1. To realize these potential gains from mechanical inputs such as tractors we need to look for the factors that inhibit the process of mechanization. In particular, studies are needed to see if there are market distortions in the form of government subsidies or otherwise that adversely affect incentives across farm size categories and regions.

Returns to Scale

The estimated returns to scale parameter for this study was observed to be 0.991. Statistically, it was found that it is not different from unity, at the 1% level of significance. This means that constant returns to scale are experienced by the Valley's agriculture. This finding has implications for the optimal scale of farm operations. Constant returns to scale implies that

any scale of operations is acceptable on efficiency grounds. Thus, if government is seeking to influence the scale of farm operations, then it would have to be justified on grounds other than efficiency such as institutional or cultural.

Structural Differences Among Farms

The hypothesis that farms in different farm size categories might be operating on different production functions could not be accepted at the 1% level of statistical significance. In terms of our study objective this means that there is not enough evidence to suggest that the sample farms in the different farm size categories operate on different production functions. That is, no fundamental structural differences exist between the sample farms and it is appropriate to pool information about them in one data set while dealing with matters of production technology.

However, we might observe at 6% level of significance that the farms in the small farm size category "12.5 or less" acres, operate on a production function with higher intercept than the rest of the farm size categories. This result may be interpreted to mean that some initial differences, whether in terms of resource endowments such as better quality of soil, or management advantages, exist that place the small farms on a higher production function. In this regard, this study identifies certain characteristics that could be responsible for placing small farms on a higher production function. That is, small farms are mostly owner-operated; allocate major portion of their operated land to growing wheat and maize; and make intensive use of manual labor and animal/tractor inputs; relative to the large and medium farms.

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