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THE NATURE OF TECHNOLOGICAL CHANGE AND AGGREGATE PRODUCTION FUNCTION IN PAKISTAN'S AGRICULTURE

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I. INTRODUCTION

Production function shifts have been recognized as an important factor in the agricultural developments of the U.S.,[1] Japan[2] Taiwan[3] and Korea[4]. In case of Pakistan major portion of the increase in agricultural output during the latter half of the 1960s has been largely ascribed to the shift of the function [27]. The affect of these shifts on factor input use is of crucial importance to a labour surplus capital scarce developing country such as Pakistan. The present study focuses on some of these issues relating to Pakistan. The objectives of the paper are three-fold. The first objective is to get an estimate of technological change based on the Solow Model [26]. Secondly the paper tries to investigate whether technological change in Pakistan s

[1] See [14].

[2] For the Japanese agriculture, production function shifts accounted for 93 percent of the growth in agricultural value added during the period 1876-1969 [28].

[3] Similarly according to [16] the agricultural sector in Taiwan did well during the two decades from 1951-70 when than 70 percent of the growth may be attributed to technological change.

[4] The most important aspect of agricultural growth in Korea is that prior to the Korean war major part of the increase in agricultural output growth was accounted for by increased use of the inputs. After the war, however increase in productivity has been an important source of growth accounting for 45 percent of the growth in agricultural output. This increase in agricultural output growth has largely been ascribed to institutional arrangements, increase in the supply of inputs such as fertilizers and insecticides better irrigation facilities, improvement in education of the farmers, development of the infrastructure and better marketing facilities [2]. In case of Phillipines, however only 26 percent of the growth in value added has been attributed to productivity and the percentage falls further to 18 percent in terms of agricultural output [7].

agriculture has been neutral to scale or other wise. This objective has been achieved by studying the relationship between technological change and the capital labour ratio in agriculture. Moreover partial productivity indexes have been computed to find out whether technological progress in Pakistan's agriculture is of the yield-augumenting or labour displacing type. Such partial productivity indexes are a good measure of technological change especially if technological change is neutral. The importance of agricultural labour productivity index also stems from the fact that it is an indicator of the level of living. And finally the paper experiments with three functional forms namely, the Linear the Semi-Log and the Log-Linear, to find out which functional form is more appropriate for Pakistan's agriculture.

The paper draws heavily on Solow's study on "Technical Change and the Aggregate Production Function" / 26 /.

The outline of the paper is as follows:- Section II discusses the methodology and the data estimation. Section III contains the estimates of technological change. In this section we also study whether technological change was of the yield-augumenting or labour displacing type and therefore, whether it was neutral to scale or otherwise. In Section IV aggregate production functions have been estimated for Pakistan's agriculture using different functional forms. The policy implications emerging from the study are discussed in Section V while Section VI summarises the study and presents the main conclusions.

II. THEORETICAL FRAMEWORK AND THE DATA

The Solow Model[5] rests on the assumption that factors are paid according to their marginal product. The model tries to segregate variations in output per head due to technical change from those on account of capital per head. First estimates of ΔA are obtained which are the yearly shift factors and then A(t) which is the cumulative shift factor and which may

[5] *Solow [26] writes the aggregate production function as*

$$Q = F(K, L, t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (i)$$

where Q is output K is capital L is labour and t is the time trend variable. Assuming neutral shifts in the production function the production function is written as

$$Q = A(t)\, f(K, L) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (ii)$$

where A(t) is the cumulative shift factor.

By differentiating equation (ii) with respect to time and dividing by Q he obtains

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + A\frac{\partial f}{\partial K}\frac{\dot{K}}{Q} + A\frac{\partial f}{\partial L}\frac{\dot{L}}{Q} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (iii)$$

where dots denote time derivatives. The relative shares of capital and labour are $w_k = \frac{\partial Q}{\partial K}\frac{K}{Q}$ *and* $w_L = \frac{\partial Q}{\partial L}\frac{L}{Q}$ *respectively (where* $\partial Q/\partial K = A\,\partial f/\partial K$ *and* $\partial Q/\partial L = A\,\partial f/\partial L$*).*

By substituting the relative share of capital and labour in equation (iii) Solow obtains equation (iv)

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + w_K\frac{\dot{K}}{K} + w_L\frac{\dot{L}}{L} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (iv)$$

When all the inputs have been categorised either as capital and labour and under constant returns to scale $w_L + w_K = 1$*. Since the model rests on the assumption that factors are paid their marginal product the model implicity assumes the hypothesis of Euler's theorm.*

By letting $Q/L = q$*,* $K/L = k$ *and* $w_L = 1 - w_K$ *equation (iv) has been regritten as*

$$\frac{\dot{q}}{q} = \frac{\dot{A}}{A} + w_K\frac{\dot{k}}{k} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (v)$$

also be termed as a 'rough profile' of technical change.

$$\Delta A = \Delta\frac{Q}{L} / \frac{Q}{L} - W_K \Delta\frac{K}{L} / \frac{K}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where,

$\frac{Q}{L}$ = Agricultural valued added divided by the agricultural labour force.

$\frac{K}{L}$ = Capital stock divided by the agricultural labour force.

W_K = Share of capital.

First estimates of ΔA are obtained by the use of equation (1).

$$A(t+1) = A(t) / 1+\Delta A / \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Then by letting A(1953-54) = 1, the A(t) series have been computed by the use of equation (2).

In order to apply the model time series data on three variables are required. Agricultural output or value added per unit of labour, capital per unit of labour and the share of capital. These data are contained in Table 1. (The data used for computing these data are in the Appendexes). In the absence of agricultural output series the agricultural value added by major and minor crops has been used. The series on capital stock are composite. They include rent, capital cost on private and public tubewells, tractors and livestock. The series on rent, capital cost on private and public tubewells, tractors and livestock were obtained by multiplying the physical quantities of cultivated area, private and public tubewells, tractors and livestock by their respective prices in 1966-67. The capital stock series does not include expenditures on farm implements, farmer's dwellings and other possessions. The series are, therefore understated. The rate of growth of the capital

stock series might have been under-estimated or over-estimated depending on whether the left out capital inputs were growing at a faster or slower rate respectively as compared with the capital stock series. The data on agricultural labour force, livestock, tubewells and tractors as estimated and adjusted for [27] have been used in the present study. The share of capital has been obtained from [27]. Since capital includes land, the factor share weights for land and capital have been aggregated to get total capital share.

III. THE NATURE OF TECHNOLOGICAL CHANGE

The A(t) series increased at the annual compound rate of 1.1 percent (Table No.1). Figure I shows that during the 1950s there was a declining trend, while a slight reversal is discernible during the early 1960s. The rising trend of the A(t) series gained momentum during the latter part of the 1960s, when the A(t) series increased at the annual compound rate of 7 percent during the sub-period 1964-65 to 1969-70.

The only possible comparison of our A(t) series is with the total factor productivity index computed by the author in an earlier study [27]. The authenticity of our A(t) series is established by the fact that it resembles the total factor productivity index to a great extent, with both the estimates growing at the annual compound rate of 1.1 percent. The annual compound rates of growth of the two series during the smaller sub-periods are also the same with the

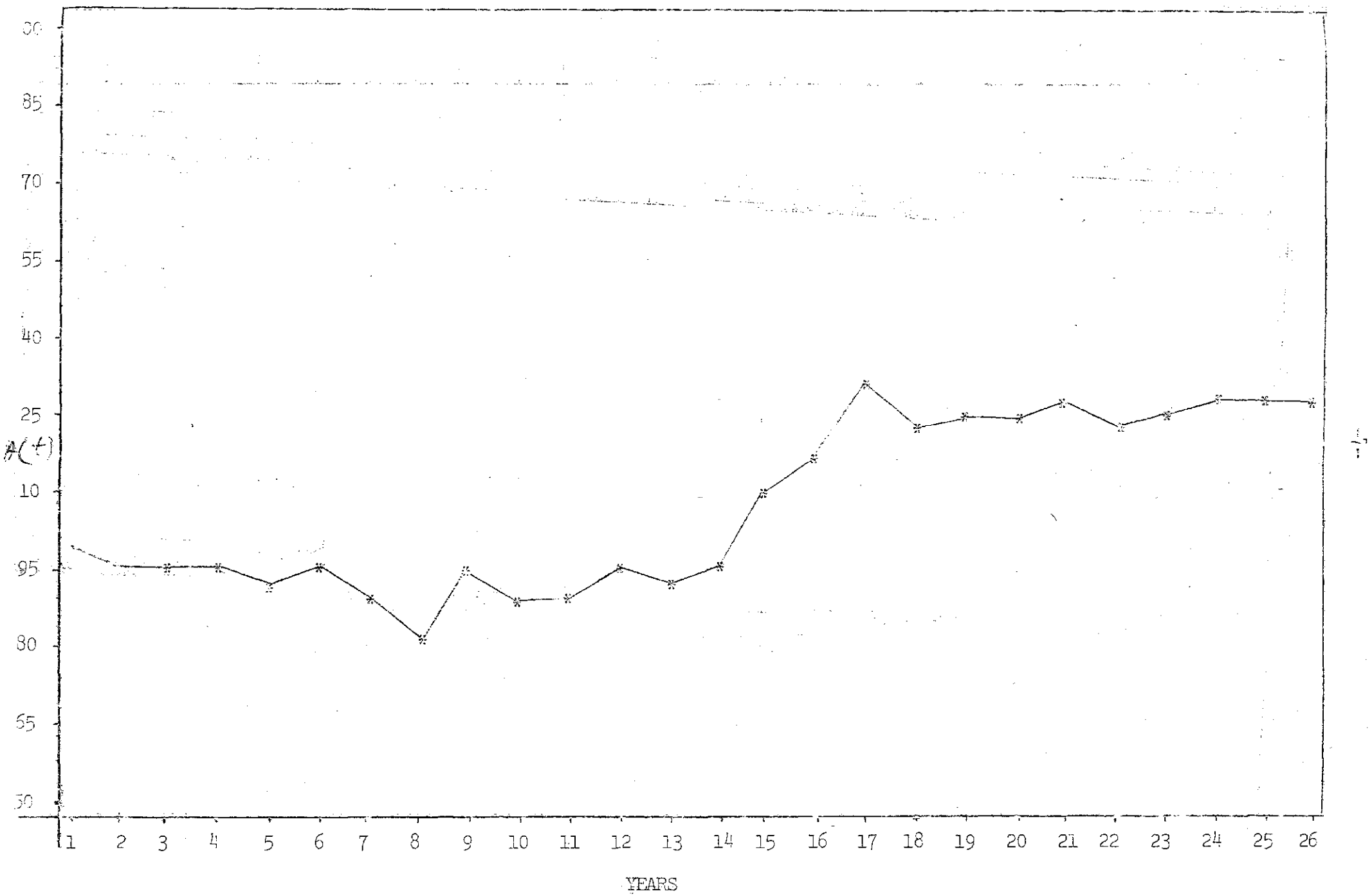
Table No. 1

Computation of AA and $A(t)$

Years	Capital Stock (Incl. Rent) (In Million Rupees)	Share of Capital	Agri. Value Added Per Agricultural Labour (In Rupees)	Capital Stock Per Agricultural Labour (In Rupees)	ΔA	$A(t)$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1953-54	7565.42	.571	721.66	1204.68	-.033	1.000
1954-55	7353.74	.562	682.46	1161.73	.008	.967
1955-56	7470 58	.564	690.60	1170.94	-.018	.974
1956-57	7666.56	.556	664.99	1132.43	-.019	956
1957-58	7827.38	.547	639.39	1093.21	.015	.938
1958-59	8003.50	.543	638.68	1060.07	-.036	.952
1959-60	8087.74	.530	602.14	1019.89	-.104	.918
1960-61	8726.26	.518	524.97	972.83	.170	.823
1961-62	8778.32	.511	606.36	945.94	-.059	.963
1962-63	9107.86	.512	572.05	949.72	.012	.906
1963-64	9122.36	.512	570.07	922.38	.036	.917
1964-65	9517.76	.515	598.81	947.04	-.031	.950
1965-66	9869.06	.520	586.97	966.61	.051	.921
1966-67	10117.28	.523	620.39	977.51	.152	.968
1967-68	10215.42	.522	713.44	973.82	.061	1.115
1968-69	10248.24	.519	761.19	984.46	.128	1.183
1969-70	10285.32	.522	863.12	995.67	-.081	1.334
1970-71	10580.64	.531	788.72	986.08	.027	1.226
1971-72	10808.28	.524	814.27	995.24	.002	1.259
1972-73	10977.94	.525	815.21	999.81	.035	1.256
1973-74	11255.94	.528	849.46	1014.05	-.055	1.300
1974-75	11659.36	.534	814.08	1039.16	.040	1.229
1975-76	11961.98	.538	852.91	1054.85	.002	1.278
1976-77	12241.96	.541	860.73	1068.23	.010	1.281
1977-78	12491.20	.544	870.21	1078.69	.006	1.294
1978-79	12728.92	.546	883.59	1087.94	-	1.302

Sources: For Column 2: Data generated by / 27 /.
For Column 3: / 27 /. The weights for land and capital have been aggregated.
For Column 4: Agricultural value added obtained from / 22 / divided by agricultural labour force obtained from / 27 /.
For Column 5: Column 2 divided by agricultural labour force obtained from / 27 /.

FIGURE 1


90
85
70
55
40
25
10
95
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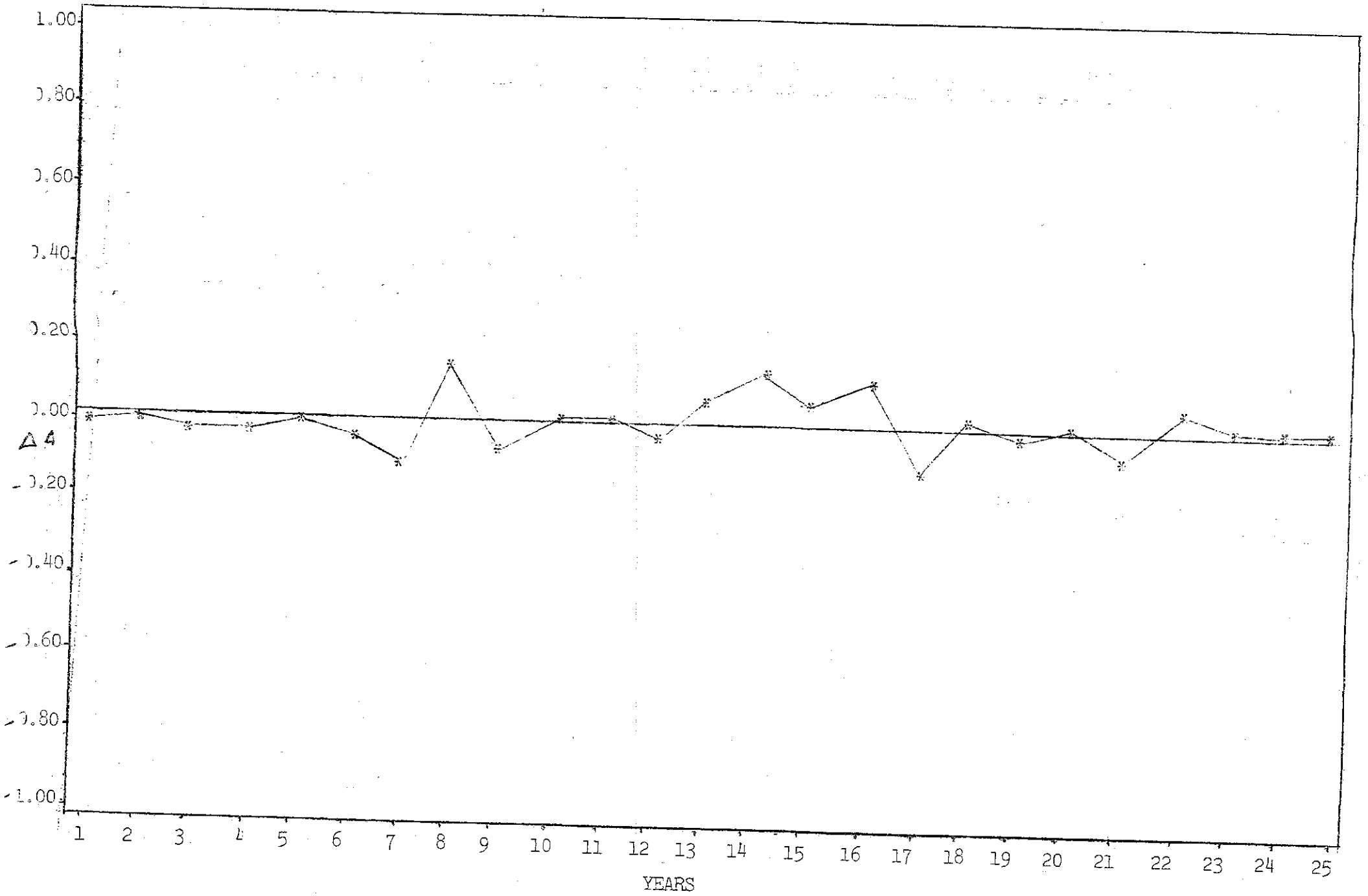
A(t)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
YEARS

FIGURE II


1.00
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- 0.40
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
YEARS

exception of the last sub-period. During the sub-period 1974-75 to 1978-79 the A(t) series increased at the annual compound rate of 1.5 percent only. The increase being more pronounced for the total factor productivity index, which increased at the rate of 2 percent per annum.

Figure II shows that there were no violent fluctuations in ΔA, depicting more or less regular movements around a fixed mean. The first major break-through occuring in 1960-61, followed by increase in 1966-67 and 1968-69, while sharpest decline occured in 1959-60.

One of the objectives of the present study is to investigate whether technological change in Pakistan's agriculture was neutral or non-neutral[6]. This objective has been achieved by studying the relationship between ΔA's which are the successive shift factors and the capital labour ratio i.e. $\frac{K}{L}$. A scatter of ΔA against K/L as shown in Figure III, indicates a negative relationship, which is also reflected by the negative regression coefficient of -0.00023 which, however, is not significant at the conventional significance levels[7]. The negative relationship between ΔA and $\frac{K}{L}$ implies that technological change in Pakistan's agriculture was not just neutral to scale, but was infact, labour augumenting[8].

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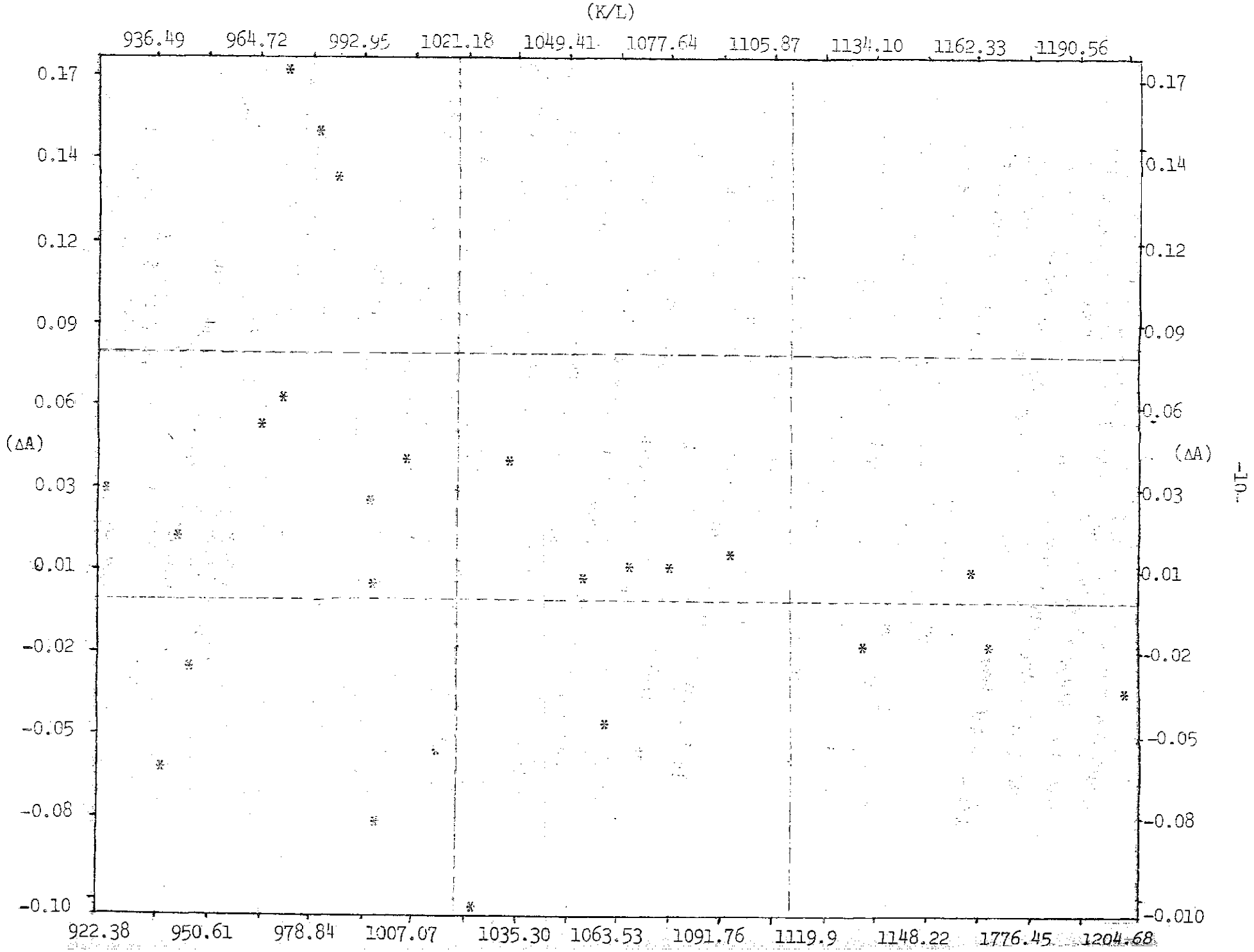
[6] Following Hicks we define neutral technological change as shifts in the production function which do not affect the marginal rates of substitutional at given capital labour ratios.

[7] The estimated coefficient is significant at the 20 percent level.

[8] As suggested by one of the discussants the relationship between ΔA and $\Delta\frac{K}{L}$ was also studied. Both the scatter of ΔA against $\Delta\frac{K}{L}$ and the regression coefficient indicate no trace of a relationship between these two variables.

Figure III: Scattergram of ΔA Against K/L



These results are further reinforced by distinguishing between two types of technological changes in agriculture: (1) the biological and chemical innovations which mainly affect yields. (2) mechanical technology which is generally assumed to be of the labour displacing type[9]. The identity between average agricultural value added per worker, the average yield per acre and the land-labour ratio[10] is expressed in equation (3).

$$\left(\frac{Q}{L}\right)_t = \left(\frac{Q}{N}\right)_t \left(\frac{N}{L}\right)_t \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

Where.

$\frac{Q}{L}$ = Average agricultural value added per agricultural labour.

$\frac{Q}{N}$ = Average yield per acre.

$\frac{N}{L}$ = Land-man ratio.

In terms of equation (3), the effect of biological chemical innovations is to increase agricultural value added per agricultural labour $(\frac{Q}{L})$ by increasing average yield per acre $(\frac{Q}{N})$. The effect of mechanical technology is to increase agricultural value added per agricultural labour $(\frac{Q}{L})$ through higher acreage per agricultural labour $(\frac{N}{L})$.

Equation (4) is obtained by differenciating equation (3) with respect to time.

$$\frac{\delta}{\delta t}\left(\frac{Q}{L}\right) / \left(\frac{Q}{L}\right) = \frac{\delta}{\delta t}\left(\frac{Q}{N}\right) / \left(\frac{Q}{N}\right) + \frac{\delta}{\delta t}\left(\frac{N}{L}\right) / \left(\frac{N}{L}\right) \ldots\ldots\ldots\ldots \qquad (4)$$

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[9] *The relationship between yield-increasing technological change, labour saving technological change and the land-man ratios is such that while yield-increasing technological change can occur both with rising and falling land-man ratio, labour-saving technological change can be rationalised only with a rising land-man ratio* [29].

[10] *See* [29].

Equation (4) states that the rate of change of agricultural value-added per person is a function of the rate of change of agricultural yields and land-labour ratio in agriculture. The model is based on the assumption that total labour utilization and the size of the agricultural labour force are proportionately related to each other.

Table 2 shows the compound rates of growth of these three ratios during different subperiods in Pakistan. The Table shows that during the sub-period 1953-54 to 1959-60 agricultural labour productivity declined at the annual compound rate of 2.9 percent, mainly on account of decline in the land-man ratio. The land-man ratio declined because while cultivated area increased slowly agricultural labour force increased at a rapid rate (See Appendix I). During the sub-period 1959-60 to 1964-65 the decline in agricultural labour productivity was much smaller. During this sub-period although the land-man ratio was still quite low, this was compensated by improvement in yields on account of increase in agricultural value added. During the sub-period 1964-65 to 1969-70 agricultural labour productivity increased at the rapid rate of 7.6 percent per annum. This increase in agricultural labour productivity was entirely accounted for by increase in yields, mainly due to increase in agricultural value added at the spectacular rate of 8.2 percent per annum. During 1969-70 to 1974-75 labour productivity in agriculture declined on account of decline in the land-man ratio due to increase in agricultural labour force. During 1974-75 to 1978-79 agricultural value added per person increased once again due to improvement in yields, the annual compound rate of growth of the land-man ratio, though still negative, improved somewhat.

Table No.2

Compound Rates of Growth of Key Agricultural Variables in Pakistan During Different Sub-Periods

Sub-Periods	Agricultural Value Added Per Agricultural Worker (Q/L)	Agricultural Value Added Per Cultivated Area (Q/N)	Land-Man Ratio (N/L)
1953-54 to 1959-60	-2.9	-0.1	-2.8
1959-60 to 1964-65	-0.1	2.1	-2.2
1964-65 to 1969-70	7.6	7.6	0.0
1969-70 to 1974-75	-1.2	0.2	-1.4
1974-75 to 1978-79	2.6	2.8	-0.2

Note.- The growth rates have been computed from Appendix IV.

The analysis of the three ratios clearly shows that the nature of technological change in Pakistan's agriculture has been of the yield augumenting type. During the sub-periods when agricultural labour productivity per person grew it was wholly accounted for by increase in yields. Moreover, mechanical technology in the form of tractors has not led to an increase in the land-man ratio as was likely to happen if tractors led to labour displacement.

Increase in crop output due to higher yields increases the demand for labour on account of harvesting and threshing provided mechanical harvesters and threshers are not used. Ghaffar / 6 / and Ghulam Mohammad / 17 / have shown that because of increase in cropping intensity and in acreage of crops which are more labour intensive, labour input on tubewell farms is higher than non-tubewell farms. Kaneda and Ghaffar / 13 / find that the labour input on tubewell farms is 57 percent higher as compared with non-tubewell farms. Similarly, Leslie Nulty / 19 / observed that increase in the supply of irrigation water from the tube-wells leads to more intensive use of the labour input. Moreover, there is ample evidence to suggest that by increasing yields, enabling farmers to practise double and multiple cropping and encouraging labour intensive cultural practices the biological and chemical innovations increase labour requirements / 29 /[11].

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[11] *The labour augumenting impact of biological and chemical innovations have been studied by / 24 /, / 6 /, / 9 /.*

Pakistan's agricultural growth may be thought of as similar to the Japanese experience [28] during the early phases of agricultural development in that country and to Korea [2] prior to 1960. In both these countries technological change was initially of the yield augumenting type. However, lately due to outmigration of agricultural labour in Japan, the contribution of land-man ratio in increasing agricultural labour productivity has increased[12]. In Korea also, from 1960 onwards mechanical technology has been used rather widely along with the biological and chemical innovations.

According to [3], [6], [9], [11] and [13] tractor mechanization leads to reduction in labour requirements. According to Bose and Clark [3] tractor mechanization led to a 50 percent reduction in the demand for agricultural labour in the Punjab. Our results come closer to Ghaffar [6] and Ahmed's [1] analysis. For example Ghaffar shows that Bose and Clark's estimate of a 50 percent reduction is exaggerated because they took account of permanent workers only and also because tractors have mainly been used for preparatory tillage operations only. According to Ghaffar reduction in the demand for labour due to

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[12] See also [29]. In Taiwan during the decade from 1913-23 increase in agricultural labour productivity came through improvement in the land-man ratio. However, from 1923 onwards till 1970 agricultural labour productivity has been increasing due to increase in yields, while the land-man ratio has been declining [16 and 29]. In the Philipines cultivated area increased faster than agricultural employment from 1950-59. Of the increase in agricultural labour productivity 74 percent was accounted for by increase in yield until 1956. During 1959-69 the land-man ratio declined and increase in labour productivity came about through increases in yields [7]. In Mexico there is technological dualism where the modern sector has adopted both land augumenting as well as labour saving technological change and the other sector using traditional technology. In this sector there is surplus labour due to which there is slow increase in agricultural labour productivity [29].

tractor mechanization was not more than 5 to 10 percent. Ahmed / 1 / shows that due to mechanization there has been a one third reduction in the number of permanent workers, but this has been compensated by a corresponding increase in the number of family workers. Using survey data Salam / 25 / shows that the use of hired labour on sample tractor farms was relatively higher as compared with bullock farms.

To sum up, our analysis shows that technological change has been of the land-augumenting type in Pakistan. Mechanical technology in the form of tractors has not led to displacement of labour as is reflected by the declining land-man ratio. Since the yield increasing type of technological change increases labour requirements, the foregoing analysis shows that technological change has been labour augumenting in Pakistan.

IV. THE AGGREGATE PRODUCTION FUNCTION

In this section aggregate production functions have been estimated for Pakistan's agriculture for the period 1953-54 to 1966-67 and 1967-68 to 1978-79. Most studies which have estimated production functions for Pakistan's agriculture are based on cross section data of sample farms. The agricultural production function estimated in the econometric model / 18 / is the only study in which an aggregate production function has been estimated for the Pakistan agriculture for the period 1959-60 to 1978-79. However, our study differs from / 18 / in the following respects: Firstly, in / 18 / a Cobb-Douglas production function has been

estimated, whereas our study experiments with several functional forms and tries to determine which functional form is more appropriate for the Pakistan agriculture. Secondly, / 18 / does not take technological change into account. Output as a function of the inputs alone is likely to give a distorted picture because of the shift parameter / 26 /. The present study takes account of technological change. Thirdly, / 18 / estimates elasticities of agricultural output with respect to each of the individual inputs while in the present study, in order to remove multi-collinearity, we have aggregated the different inputs. Any lastly, the production function estimated in / 18 / is for the period 1959-60 to 1978-79, whereas, our study covers the 1950s as well, thus enabling us to study the performance of the agricultural sector during the pre-Green Revolution period as well.

Functional Forms

The following three equations were used in the estimation of the production functions.

$$\frac{Q(t)}{L(t)} / A(t) = a + b \frac{K(t)}{L(t)} \quad \ldots\ldots\ldots\ldots \quad \text{Linear(5)}$$

$$\frac{Q(t)}{L(t)} / A(t) = a + b \ln \frac{K(t)}{L(t)} \quad \ldots\ldots\ldots\ldots \quad \text{Semi-Log(6)}$$

$$\ln \frac{Q(t)}{L(t)} / A(t) = a + b \ln \frac{K(t)}{L(t)} \quad \ldots\ldots\ldots\ldots \quad \text{Log-Linear(7)}$$

Where,

Q (t)	=	agricultural value-added in million Rs.
L (t)	=	agricultural labour force in millions.
K (t)	=	agricultural capital stock including rent in million Rs.
A(t)	=	index of technological change.
a	=	constant term.
b	=	coefficient to be estimated.

First ordinary least squares were used to estimate the equations. These estimates gave very low Durbin-Watson statistic indicating the presence of positive autocorrelation. Therefore, we employed the Orcutt-Cochrane iterative technique to estimate the coefficients.

In order to account for technological change we have estimated separate production functions for the periods 1953-54 to 1966-67 and 1967-68 to 1978-79, the former being the pre-technological change era. Moreover, our dependent variable is agricultural value added per person deflated by the shift parameter. In this formulation the land and capital inputs have been aggregated together. The estimates obtained from the three functional forms are presented in Table 3. The estimated coefficients are significant at one percent level for all the three parametric forms. In the pre-technological change era almost 90 percent of the variation has been accounted for by the independent variable, whereas in the 1967-68 to 1978-79 sub-period 99 percent of the variation has been accounted for.

Table No. 3

Estimates of the Three Functional Forms

Equation Type	Constant Term	Estimated Coefficient	Adjusted R2	F Statistic	DW Statistic
1953-54 to 1966-67					
Linear Production Function	249.120 (6.716)*	.395 (10.974)*	.909	120.434	2.06
Semi-Log Production Function.	-2216.44 (-9.030)*	414.227 (11.700)*	.919	136.900	2.10
Log-Linear Production Function.	2.127 (5.105)*	.628 (10.459)*	.900	109.382	2.07
1967-68 to 1978-79					
Linear Production Function.	316.739 (54.832)*	.332 (58.938)*	.997	3473.65	2.01
Semi-Log Production Function.	-1712.85 (-55.340)[5]	341.667 (76.555)*	.998	5860.61	2.04
Log-Linear Production Function.	2.887 (53.89)*	.519 (67,185)*	.998	4513.77	2.02

Note:- Figures in the parentheses are the t ratios.

* Significant at the 1 percent level.

For the purpose of showing the shift of the production function graphically we combined the two sub-periods together. The scatter of agricultural value added per agricultural labour deflated by the technological change index against agricultural inputs per agricultural labour is shown in Figure IV. The Figure shows ~~there are~~ two layers of almost parellel to each other. It appears that the set of observations observations which are lower relate to the 1950s i.e. the pre-technological change era. The set of observations which are higher depict the shift of the production function after the introduction of modern inputs.

The following variants of these models were also used to estimate the production functions.

$$\frac{Q(t)}{L(t)} = a+b\frac{N(t)}{L(t)} + c\frac{K(t)}{L(t)} + d\,t \quad \text{.....Linear} \quad (8)$$

$$\frac{Q(t)}{L(t)} = a+b\ln\frac{N((t)}{L(t)} + c\ln\frac{K(t)}{L(t)} + d\,t \quad \text{.....Semi-Log} \quad (9)$$

$$\ln\frac{Q(t)}{L(t)} = a+b\ln\frac{N(t)}{L(t)} + c\ln\frac{K(t)}{L(t)} + d\,t \quad \text{.....Log-Linear} \quad (10)$$

Where N (t) = cultivated area in million acres, all other variables are the same. In the second formulation we have estimated production functions using the same functional forms for the two sub-periods. Here, however, we have used land and capital as separate independent variables. Moreover, the dependant variable has not been deflated, instead we have used time trend as a separate variable. The estimates obtained from these equations are reported in Table 4. It is interesting to note that in the pre-technological change era, the time trend variable is negative though not significant for all the three parametric forms. The capital input is positive and significant at the one percent level for the Semi-Log and Log-Linear models and at two percent level for the Linear model.

FIGURE IV

SCATTER OF $\frac{Q(t)}{L(t)}/A(t)$ AGAINST $\frac{K(t)}{L(t)}$

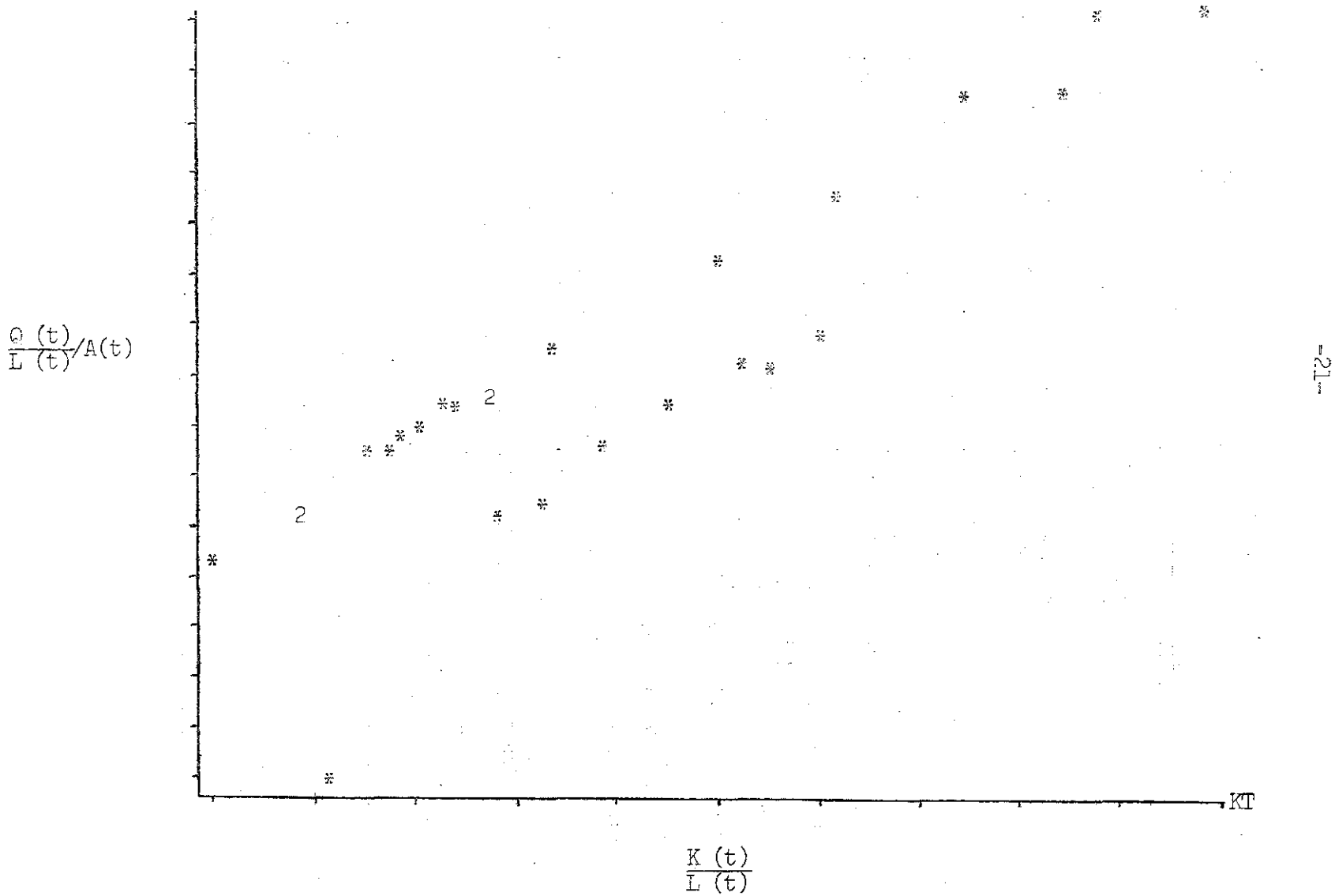

Table No. 4

Equation Type	Constant Term	Land-Labour	Capital Labour	Time	Adjusted R^2	F-Statistic	DW Statistic
1953-54 to 1966-67							
Linear Production Function.	-.076 (-.320)	.202 (.482)	1.661 (3.179)**	-.002 (-.294)	.875	29.043	1.982
Semi-Log Production Function	1.370 (8.845)*	.105 (.332)	.642 (3.573)*	-.004 (-.451)	.884	31.590	2.002
Log-Linear Production Function	.675 (2.755)***	.094 (.187)	1.002 (3.535)*	-.006 (-.506)	.864	26.432	2.024
1967-68 to 1978-79							
Linear Production Function.	-.158 (-.386)	1.786 (3.012)**	-3.867 (-3.454)*	.087 (4.164)*	.884	22.542	2.345
Semi-Log Production Function.	-1.599 (-1.527)	.598 (1.331)	-1.675 (-2.406)	.075 (3.035)**	.813	13.306	2.614
Log-Linear Production Function.	-2.730 (-2.199)	.655 (1.207)	-1.760 (-2.142)	.080 (2.733)***	.771	10.501	2.706

Note; The figures in the parentheses are the t ratios.

* Significant at the one percent level.

** Significant at the two percent level,

In the technological change era the coefficient for the time trend variable is positive and significant for all the three parametric forms. The coefficient for the capital input is negative in all the three models and is significant at the one percent level in the Linear model. The negative coefficient for capital may be due to massive increase in this input during this sub-period. The coefficient for land is significant at the two percent level in the Linear model only.

In order to determine which functional form is more appropriate for the Pakistan agriculture, the Box-Cox Test was applied to the sum of square of the residuals of the two variants of the three functional forms. The test revealed that the Semi-Log model is more appropriate than the Linear or the Log-Linear forms since its sum of squared residuals is the minimum[13].

V. POLICY IMPLICATIONS

The analysis shows that the type of technological change responsible for break through in Pakistan's agriculture has been of the yield increasing type. Increase in crop output due to higher yield gives rise to increase in labour requirements. The analysis also shows that introduction of tractors was not accompanied by a concomitant increase in the land-man ratio as was likely to happen if tractor mechanization

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[13] In the variant where land and capital have been used as separate variables, the Linear model is more appropriate than the other two models for the period 1967-68 to 1978-79.

led to labour displacement. The analysis, therefore, shows that in the modern technology Pakistan has found a way of promoting the often diametrically opposed objectives of maximizing growth and achieving distributive social justice.

The foregoing analysis also shows that the land-man ratio has been affecting agricultural labour productivity negatively. The land man ratio can be increased either by increasing cultivated area and or by reducing the numbers engaged in agricultural occupations. While there might be some constraints (in the form of irrigation water supplies etc.) with increasing cultivated area, more effective way to control the land-man variable is by reducing the rate of population growth. Reduction in the rate of population growth will help to increase acreage per man in agriculture and thus agricultural labour productivity.

And finally, the finding of the paper that tractors are not a labour displacing form of technological change should be treated with a great deal of caution. This is because the analysis is based on data for agricultural labour force which is not very reliable. More importantly it is because the analysis relates to twenty six years only. It is quite likely that over a long period of time with massive increase in tractor numbers, tractors might start displacing labour.

VI. SUMMARY AND CONCLUSIONS

Our A(t) series increased at the annual compound rate of 1.1 percent during 1953-54 to 1978-79. A declining tendency was discernible during the 1950s, whereas during the early 1960s the A(t) series started rising slowly. During the latter half of the 1960s the A(t) series rose rapidly at the annual compound rate of 7 percent.

The analysis shows that the growth of agricultural output per man has come through yielding increasing type of technological changes. Such types of innovations have been found to be labour augumenting in character. Introduction of mechanical technology in the form of tractors has not led to labour displacement as is borne out by the declining land-man ratios. The negative relationship between technological change and the capital labour ratio also implies that the net effect of different types of technological changes has been labour augumenting.

In the estimation of the aggregate agricultural production functions the coefficients obtained from the first formulation are statistically significant at the one percent level. The Box-Cox test applied to the sum of squared residuals shows that the Semi-Log model is more appropriate for Pakistan's agriculture as compared with the Linear and the Log-Linear models.

In the second formulation where land and capital have been used as separate independent variables the time trend variable is negative in the pre-technological era for all the three parametric

forms. The capital input is positive and significant during the same sub-period. In the technological change era the coefficient for the time-trend variable is positive and significant in all the models while the coefficient for capital is negative.

Our study shows that the new technology can be used to promote the often diametrically opposed objectives of maximizing growth and achieving distributive social justice. The paper shows that agricultural labour productivity can be increased through increasing yields and or the land-man ratio. Improvement in yields can be brought about by encouraging the use of modern inputs. The level of living can also be increased by increasing the land-man ratio by reducing the rate of population growth.

Appendix - I

Agricultural Inputs in Pakistan (1953-54 to 1978-79)

Years	Agricultural Value-Added (in Million Rupees)	Land (Cultivated Area (in Million Acres)	Agricultural Labour Force (in Millions)	Livestock (in Million Heads)	Private Tube-wells (in Numbers)	Public Tube-wells (in Numbers)	Tractors (in Numbers)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1953-54	4532	38.39	6.28[e]	6.5	999	-	-
1954-55	4320	37.86	6.33[e]	6.1	1300	-	437
1955-56	4406	38.70	6.38	6.1	1600	-	546
1956-57	4502	39.56	6.77[e]	6.3[e]	1900	-	804
1957-58	4578	40.14	7.16[e]	6.5[e]	2200	-	1241
1958-59	4882	40.04	7.55[e]	6.7[e]	3300	-	1598
1959-60	4775	40.80	7.93	6.8	4600	256	3642
1960-61	4709	44.76	8.97	6.9	8000	1264	4192
1961-62	5127	44.23	9.28[e]	7.0	13000	1482	6495
1962-63	5486	44.55	9.59[e]	7.5	18400	2052	8943
1963-64	5638	45.30	9.89	7.0	25000	2206	11180
1964-65	6018	46.26	10.05	7.5	31600	2206	12593
1965-66	5993	47.54	10.21	7.7[e]	40207	2344	13990
1966-67	6421	47.60	10.35[e]	7.9	51327	2626	17753
1967-68	7484	48.00	10.49	7.6	62163	3708	18991
1968-69	7924	47.67	10.41[e]	7.3	72149	5216	22420
1969-70	8916	47.63	10.33	7.0	79223	6266	26485
1970-71	8463	47.47	10.73	7.9[e]	89157	6527	28535
1971-72	8843	47.16	10.86	7.9	98755	6657	30277
1972-73	8951	47.23	10.98[e]	8.0	109541	7384	29879
1973-74	9429	47.87	11.10[e]	8.1	120506	7572	33173
1974-75	9134	48.29	11.22[e]	8.2	144271	8097	37877
1975-76	9672	48 98	11.34[e]	8.3	150117	8495	46032
1976-77	9864	48.81	11.46[e]	8.4	156910	10120	58047
1977-78	10076	49.28	11.58[e]	8.4	160901	11686	65759
1978-79	10545	49.79	11.70[e]	8.5	166948	11535	76269

Sources :- For Column 2: / 22 /.
For Columns 3 and 5: / 23 /.
For Column 4: / 10 /.
For Column 6: / 8 17 and 23 /.
For Column 7 Unpublished data made available by Pakistan's Water and Power Development Authority.
For Column 8: / 22 /.

Note:- This Table has been taken from / 27 /.

[e]Denotes our own estimates which have been arrived at by means of linear interpolation.

Appendix - II

Factor Prices (in 1966-67) Used in the Computation of Cost on Factor Inputs

Land

Rents Received by Landlords Separated by Size of Holding in the Punjab

Rs. (per acre)

Less Than 10 Acres	10-25 Acres	26-50 Acres	51-100 Acres	101-250 Acres	251-500 Acres
94	128	160	152	148	132

Labour: Wages of Hired Agricultural Labour Rs.2.48 per day.

Capital Capital Cost of Private Tubewells.

	Gujranwala/ Sialkot Region (Rs.)	Multan/ Sahiwal Region (Rs.)	Average of the Two Region (Rs.)
Electric Tubewells:-	6,000	9,164	7,582
Deisel Tubewells:-	9,322	12,464	10,893

Livestock:

	Price Per Animal (Rs.)
Cattle	438.73
Buffaloes	285.66
Camels	571.84
Horses	612.57
Donkeys	104.06

Tractor:

The ex-Karachi Selling Price of a 45 Horsepower Masy Ferguson Tractor~Rs. 12 585.78.

Sources: The data on rent is from / 4 /.
The data on agricultural wages is from / 10 /.
The data on the capital cost of private tube-wells is from / 19 /.
The data on prices of agricultural animals is from / 21 /. The data on the price of tractors is from the ADBP un-published data.

Note:- This Appendix has been taken from / 27 /.

Appendix - III

Total Cost on Land, Labour and Capital in Pakistan During 1953-54 to 1978-79

(In Million Rupees)

Year	Total Labour Cost	Total Capital Cost	Total Rent
1953-54	5684.7	2427.6	5137.82
1954-55	5729.9	2286.5	5067.24
1955-56	5775.2	2290.9	5179.68
1956-57	6128.2	2371.9	5294.66
1957-58	6481.2	2455.1	5372.28
1958-59	6834.3	2544.3	5359.20
1959-60	7178.2	2627.3	5460.44
1960-61	8119.6	2737.0	5989.26
1961-62	8400 3	2858.7	5919.62
1962-63	8680.9	3145.6	5962.26
1963-64	8952 4	3058.2	6064.16
1964-65	9097.3	3326.3	6191.46
1965-66	9242.1	3507.5	6361.56
1966-67	9368.8	3747.9	6369.38
1967-68	9495.5	3791.1	6424.32
1968-69	9423.1	3868.0	6380.24
1969-70	9350.7	3909.4	6375.92
1970-71	9712.8	4227.4	6353.24
1971-72	9830.5	4496.4	6311.88
1972-73	9939.1	4656.8	6321.14
1973-74	10047.7	4848.7	6407.24
1974-75	10156.3	5195.9	6463.46
1975-76	10265.0	5405.1	6556.88
1976-77	10373.6	5710.8	6531.16
1977-78	10482.2	5895.5	6595.70
1978-79	10590.8	6077.0	6651.92

Sources:- This data has been computed by multiplying the input quantities in Appendix - I by the input prices in Appendix - II. The method of computation has discussed in detail in Appendix - I in / 27 /.

Year	(Q/L) Agri. Value Added ÷ Agriculture Labour Force	(Q/L) Index	(Q/N) Agriculture Value Added ÷ Cultivated Area	(Q/N) Index	(N/L) Land Labour Ratio	(N/L) Index
1953-54	721.66	119.8	118.05	100.9	6.11	118.6
1954-55	682.46	113.3	114.10	97.5	5.98	116.1
1955-56	690.60	114.7	113.85	97.3	6.07	117.9
1956-57	664.99	110.4	113.80	97.2	5.84	113.4
1957-58	639.39	106.2	114.05	97.5	5.61	108.9
1958-59	638.68	106.1	121.93	104.2	5.30	102.9
1959-60	602.14	100.0	117.03	100.0	5.15	100.0
1960-61	524.97	87.2	105.21	89.9	4.99	96.9
1961-62	606.36	100.7	115.92	99.1	4.77	92.6
1962-63	572.05	95.0	123.14	105.2	4.65	90.3
1963-64	570.07	94.7	124.46	106.3	4.58	88.9
1964-65	598.81	99.4	130.09	111.2	4.60	89.3
1965-66	586.97	97.5	126.06	107.7	4.66	90.5
1966-67	620.39	103.0	134.89	115.3	4.60	89.3
1967-68	713.44	118.5	155.92	133.2	4.58	88.9
1968-69	761.19	126.4	166.23	142.0	4.58	88.9
1969-70	863.12	143.3	187.19	160.0	4.61	89.5
1970-71	788.72	131.0	178.28	152.3	4.42	85.8
1971-72	814.27	135.2	187.51	160.2	4.34	84.3
1972-73	815.21	135.4	189.52	161.9	4.30	83.5
1973-74	849.46	141.1	196.97	168.3	4.31	83.7
1974-75	814.08	135.2	189.15	161.6	4.30	83.5
1975-76	852.91	141.6	197.47	168.7	4.32	83.9
1976-77	860.73	142.9	202.09	172.7	4.26	82.7
1977-78	870.21	144.5	204.46	174.7	4.26	82.7
1978-79	901.28	149.7	211.79	181.0	4.26	82.7

Source:- Data on agricultural value added is from / 22 /.
Data on agricultural labour force as estimated and adjusted for / 27 /.
Data on cultivated area is from / 23 /.

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