FUNCTIONAL ANALYSIS AND OPTIMIZATION OF FARM RESOURCES AND MAXIMIZATION OF WHEAT PRODUCTION

Production function:

Multiple regression analysis was used as the analytical tool to study the input-output relationships and productivity of various inputs involved in the production of wheat. Thus, regression equations were developed to express yield of wheat as a function of various inputs used during the production process of wheat.

Cobb-Douglas type of regression equations were developed for further economic analysis. The regression equations of Cobb-Douglas function of wheat production for different size of holdings are given below:

Regression equations of wheat:

1. Below 2 hectares size group (N = 50)

\[
Y = 0.002989 x_1^{0.3997} x_2^{0.2175} x_3^{0.1443} x_4^{0.6732} x_5^{0.4721} \\
(0.1126)(0.2256)(0.2025)(0.1027)(0.0956)
\]

\[R^2 = 0.9961\]

2. 2 - 4 hectares size group (N = 30)

\[
Y = 0.0004422 x_1^{0.3714} x_2^{0.2357} x_3^{0.1454} x_4^{0.6441} x_5^{0.4552} \\
(0.1102)(0.2421)(0.1467)(0.0978)(0.1165)
\]

\[R^2 = 0.9012\]

3. 4 hectares and above (N = 20)

\[
Y = 0.0003785 x_1^{0.3075} x_2^{0.2172} x_3^{0.1451} x_4^{0.7714} x_5^{0.4651} \\
(0.1012)(0.1654)(0.1631)(0.1205)(0.1015)
\]

\[R^2 = 0.6454\]
(4) For all farmers: \( N = 100 \)

\[
Y = 0.0001899 X_1 + 0.2485 X_2 + 0.1451 X_3 + 0.7284 X_4 + 0.4954 X_5
\]

\[
(0.1056) (0.2599) (0.2732) (0.0134) (0.0975)
\]

\[ R^2 = 0.8115 \]

Where \( Y \) = Yield of wheat in quintals per hectare.

\( X_1 \) = Cost of human labour (in rupees) per hectare.

\( X_2 \) = Cost of bullock labour (in rupees) per hectare.

\( X_3 \) = Cost of seed (in rupees) per hectare.

\( X_4 \) = Cost of manures and fertilizers (in rupees) per hectare.

\( X_5 \) = Cost of irrigation (in rupees) per hectare.

* Significant at 5 per cent level of significance.

** Significant at 0.1 per cent level of significance.

Figures in parenthesis show the standard error of their respective regression coefficients.

**Coefficient of multiple determination:**

Examination of multiple determination of wheat indicated that human labour \( (X_1) \), manures and fertilizers \( (X_4) \) and irrigation \( (X_5) \) explained about 89, 90, 84, and 81 per cent of the total observed variation in the yield on the farms of below 2 hectares, 2 - 4 hectares, 4 hectares and above and all farms respectively.

**Elasticities of production of farm resources:**

The Cobb-Douglas type of production function is linear in logarithms and the partial regression coefficients of production on the various inputs in the equation directly denote the elasticities of production. The elasticity of production indicates the percentage change in production associated with one per cent change in the
quantity of a particular input, keeping other resources at constant level. The elasticity of production along with test of significance and standard error for wheat under various size groups have been shown in Table X-1.

Table X-1. Elasticity of production, value of 't', standard error, coefficient of multiple determination for wheat under different size groups.

<table>
<thead>
<tr>
<th>Size group (in hectares)</th>
<th>(X_1)</th>
<th>(X_2)</th>
<th>(X_3)</th>
<th>(X_4)</th>
<th>(X_5)</th>
<th>D.F.</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression Coefficient</td>
<td>0.3997</td>
<td>0.2175</td>
<td>0.1443</td>
<td>0.6732</td>
<td>0.4721</td>
<td>-</td>
<td>0.8969</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.1126</td>
<td>0.2256</td>
<td>0.2025</td>
<td>0.1027</td>
<td>0.0956</td>
<td></td>
<td></td>
</tr>
<tr>
<td>'t' value</td>
<td>3.4125</td>
<td>1.0516</td>
<td>1.1031</td>
<td>4.6729</td>
<td>5.0923</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>2 - 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression Coefficient</td>
<td>0.3714</td>
<td>0.2357</td>
<td>0.1454</td>
<td>0.6441</td>
<td>0.4552</td>
<td>-</td>
<td>0.9012</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.1102</td>
<td>0.2421</td>
<td>0.1467</td>
<td>0.0978</td>
<td>0.1165</td>
<td></td>
<td></td>
</tr>
<tr>
<td>'t' value</td>
<td>2.9653</td>
<td>2.0211</td>
<td>2.1025</td>
<td>5.5241</td>
<td>4.3502</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>4 &amp; above</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression Coefficient</td>
<td>0.3075</td>
<td>0.2172</td>
<td>0.1451</td>
<td>0.7714</td>
<td>0.4651</td>
<td>-</td>
<td>0.8454</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.1012</td>
<td>0.1654</td>
<td>0.1631</td>
<td>0.1205</td>
<td>0.1016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>'t' value</td>
<td>3.7254</td>
<td>2.7153</td>
<td>1.2305</td>
<td>5.0539</td>
<td>4.2135</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>All farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression coefficient</td>
<td>0.3796</td>
<td>0.2486</td>
<td>0.1451</td>
<td>0.7284</td>
<td>0.4954</td>
<td>-</td>
<td>0.8115</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.1056</td>
<td>0.2598</td>
<td>0.2732</td>
<td>0.0134</td>
<td>0.0975</td>
<td></td>
<td></td>
</tr>
<tr>
<td>'t' value</td>
<td>3.5219</td>
<td>1.1052</td>
<td>1.0502</td>
<td>6.5912</td>
<td>5.3505</td>
<td>94</td>
<td></td>
</tr>
</tbody>
</table>
The examination of elasticities of production of various inputs used in the production of wheat under different size groups revealed that the coefficients of all the individual inputs except of seed and bullock labour were significant, positive and less than unity, indicating diminishing returns to each individual input. Among the significant variables, the highest elasticity of production was observed in the case of manure - fertilizers followed by irrigation and human labour in almost all the size group of farms. The production elasticity of bullock labour and seed was observed to be non-significant and lowest.

**Marginal productivities of inputs:**

The marginal physical product of an input is the increment in output forth coming from the use of its additional unit, the level of input remaining unchanged. The marginal value product is the marginal return of an input variable expressed in monetary terms and can be defined as the additional return obtained from an additional unit of input. The marginal physical and value products of various inputs on the farms of various size groups and on the farms as a whole for wheat have been given in Table X-2.

Table X-2, clearly indicates that the marginal value product of manure-fertilizer varied from Rs.6.39 on the farms of 2 - 4 hectares size group to Rs.11.85 on the farms of below 2 hectares size group. Thus, there is greater opportunity of higher returns on these farms by increasing the use of manure-fertilizers as compared to the farms of other size group. Similarly is the case with the marginal value product of irrigation which was more on the
Table X-2. Marginal physical and value products of various inputs of wheat under different size groups.

<table>
<thead>
<tr>
<th>Size group</th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
<th>$X_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 2 hectares</td>
<td>0.01380</td>
<td>0.0109</td>
<td>0.0209</td>
<td>9.0958</td>
<td>0.0666</td>
</tr>
<tr>
<td>MFP</td>
<td>1.71</td>
<td>1.35</td>
<td>2.58</td>
<td>11.85</td>
<td>8.23</td>
</tr>
<tr>
<td>MVP (Rs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 - 4 hectares</td>
<td>0.0179</td>
<td>0.0161</td>
<td>0.0252</td>
<td>0.0517</td>
<td>0.0566</td>
</tr>
<tr>
<td>MFP</td>
<td>2.21</td>
<td>1.99</td>
<td>3.12</td>
<td>6.39</td>
<td>6.99</td>
</tr>
<tr>
<td>MVP (Rs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 hectares &amp; above</td>
<td>0.0158</td>
<td>0.0154</td>
<td>0.0218</td>
<td>0.0710</td>
<td>0.0570</td>
</tr>
<tr>
<td>MFP</td>
<td>1.95</td>
<td>1.90</td>
<td>2.70</td>
<td>8.78</td>
<td>7.04</td>
</tr>
<tr>
<td>MVP (Rs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For All farms</td>
<td>0.0173</td>
<td>0.0160</td>
<td>0.0230</td>
<td>0.0575</td>
<td>0.0620</td>
</tr>
<tr>
<td>MFP</td>
<td>2.14</td>
<td>1.98</td>
<td>2.84</td>
<td>8.35</td>
<td>7.76</td>
</tr>
<tr>
<td>MVP (Rs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

farms of below 2 hectares as compared to the farms of other size group and the farms as a whole. Since, the marginal value product of human and bullock labour were not significantly higher on the farms of almost of all size group than their respective prices, there is no scope for increasing the level of these inputs in wheat production. On the contrary, the human and bullock labour already involved should be reduced to the extent where the marginal value product of the input equals to its price.

Thus, from the above discussion, it can be concluded that there is a great scope for increasing the level of manure - fertilizer and irrigation in the production of wheat to get maximum net returns from it.
Economic optimum levels:

The profits could be maximised on the wheat farms by increasing each resource to a point where its marginal value product is equal to its price. This is true only when the available capital with the wheat growers is unlimited. This assumption of unlimited capital with the farmers is very far from reality and has little practical importance. In the case of capital constraint, the maximum profit could be attained by allocating the limited capital among its various competing use in such a way that its marginal value return per unit of money investment on each resource in each use becomes equal. In case, when the marginal value products of various farm resources are not equal at the existing level of their use, the profit can be maximised by equating the marginal value product per rupee investment by shifting the resources having low marginal value product to those which have higher marginal value products.

The optimum and existing levels of various inputs alongwith their difference under limited capital for wheat under different size of farms are presented in Table X-3.

Table X-3. Optimum and existing levels of various inputs under different size of farms. (In Rs.)

<table>
<thead>
<tr>
<th>Size of farms</th>
<th>Input variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$x_1$</td>
</tr>
<tr>
<td>Below 2 hectares</td>
<td></td>
</tr>
<tr>
<td>Optimum levels</td>
<td>434.03</td>
</tr>
<tr>
<td>Existing levels</td>
<td>857.88</td>
</tr>
<tr>
<td>Difference of shifting</td>
<td>+423.85</td>
</tr>
</tbody>
</table>

Contd.....
<table>
<thead>
<tr>
<th></th>
<th>2 - 4 hectares</th>
<th>4 hectares &amp; above</th>
<th>All farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum levels</td>
<td>451.48 286.52</td>
<td>757.26 534.08</td>
<td>299.14 211.30</td>
</tr>
<tr>
<td>Existing levels</td>
<td></td>
<td></td>
<td>609.30 441.60</td>
</tr>
<tr>
<td>Difference of shifting</td>
<td>+305.78 +247.56</td>
<td>+ 33.85 -327.83</td>
<td>+410.39 -196.96</td>
</tr>
</tbody>
</table>

The comparison of optimal and existing levels of farm resources on the farms as a whole and on different size groups indicated that the optimum levels of manure-fertilizers, and irrigation on the farms of almost all the size groups and for all farms as a whole were significantly higher than that of their respective existing mean levels. On the contrary, the existing levels of human labour, bullock labour and seed on the farms of almost all size groups and for all growing wheat were significantly higher as compared to their respective optimum levels. Thus, it can be concluded that shifting and reallocation of available funds used for human labour, bullock labour and seed to the use of manure-fertilizers and irrigation may maximise the returns from wheat on the farms of almost of all size groups and for all wheat growing farms.
It is therefore suggested that the wheat growers are required to shift and reallocate the funds spent on human labour, bullock labour and seed to the extent given in Table X-3 in order to increase the level of manure-fertilizers and irrigation for maximising the returns from wheat cultivation.

On the basis of above results, it may be noted that the returns on the crop in question can be maximised simply by reallocation of limited capital (under capital constraint) because the farmer can not spend additional funds required for from his own resources nor be can borrow additional funds beyond his capacity from various financing institutions.

Now, it is desired to find out as to what extent the returns can be maximised by reallocation of the existing resources. Keeping in view this objective, regression equations at optimum levels of inputs for wheat crop has been developed for various size of farms under study, and are given below:

**Below 2 hectares size group:**

\[
Y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5
\]

\[
= 0.0002989 + 434.03^{0.3997} + 236.08^{0.2175} + 156.70^{0.1443}
\]

\[
= 731.13^{0.6732} + 512.65^{0.4721}
\]

\[
\log Y = \log 0.0002989 + 0.3997 \log 434.03 + 0.2175 \log 236.18
\]

\[
+ 0.1443 \log 156.70 + 0.6732 \log 731.13 + 0.4721 \log 512.65
\]

\[
= 1.57
\]

\[
Y = 37.15 \text{ quintals.}
\]
2 - 4 hectares size group:

\[ Y = a \cdot x_1 \cdot x_2 \cdot x_3 \cdot x_4 \cdot x_5 \]

\[ = 0.0004422 \cdot 451.48 \cdot 0.3714 \cdot 286.52 \cdot 0.2357 \cdot 176.75 \cdot 0.1454 \cdot 782.99 \cdot 0.6441 \cdot 553.35 \cdot 0.4552 \]

\[ \log Y = \log 0.0004422 + 0.3714 \log 451.48 + 0.2357 \log 286.52 \]

\[ + 0.1454 \log 176.75 + 0.6441 \log 782.99 + 0.4552 \log 553.35 \]

\[ = 1.65 \]

\[ = 44.67 \] quintals

4 hectares and above size group:

\[ Y = a \cdot x_1 \cdot x_2 \cdot x_3 \cdot x_4 \cdot x_5 \]

\[ = 0.0003785 \cdot 299.14 \cdot 0.3075 \cdot 211.30 \cdot 0.2172 \cdot 141.16 \cdot 0.1451 \cdot 750.43 \cdot 0.7714 \cdot 452.46 \cdot 0.4651 \]

\[ \log Y = \log 0.0003785 + 0.3075 \log 299.14 + 0.2172 \log 211.30 \]

\[ + 0.1451 \log 141.16 + 0.7714 \log 750.43 + 0.4651 \log 452.46 \]

\[ = 1.6094 \]

\[ Y = 40.69 \] quintals

All farms:

\[ Y = a \cdot x_1 \cdot x_2 \cdot x_3 \cdot x_4 \cdot x_5 \]

\[ = 0.0001899 \cdot 392.27 \cdot 0.3796 \cdot 256.90 \cdot 0.2496 \cdot 149.94 \cdot 0.1451 \cdot 752.61 \cdot 0.7283 \cdot 511.95 \cdot 0.4954 \]

\[ \log Y = \log 0.0001899 + 0.3796 \log 392.27 + 0.2496 \log 256.90 \]

\[ + 0.1451 \log 149.94 + 0.7283 \log 752.61 + 0.4954 \log 511.95 \]

\[ = 1.6149 \]

\[ Y = 41.20 \] quintals
An examination of the regression equations developed for the farms of different size groups and for all farms under study under optimum levels of input revealed that the yield of wheat can be maximised from their existing levels of 29.61, 36.53, 31.29 and 33.02 quintals on the farms of below 2 hectares, 2 - 4 hectares, 4 hectares and above and the farms as a whole, respectively at existing levels of input variables to 37.15, 44.67, 40.68 and 41.20 quintals per hectare on the respective farms at optimum levels of input under capital constraints simply by reallocation of inputs indicating thereby a net difference in yield of wheat per hectare between existing and optimum levels of farm inputs, being 7.54, 9.34, 9.39 and 9.18 quintals for respective farms of various size groups. The net difference in the output per hectare at existing and optimum of inputs was worked out at Rs.931.94, Rs.1030.82, Rs.1116.60 and Rs.1011.05 on the farms of below 2 hectares, 2 - 4 hectares, 4 hectares above above and for all farms respectively.

Thus, it can be concluded that from optimization and reallocation of farm resources, the yield of wheat can be increased significantly from their existing levels under capital constraint, resulting into additional net income of about Rs. one thousand over and above original level of net profit per farm. The above facts also indicated that the maximum additional net return was observed being Rs.1160.60 per hectare on the highest size group followed by medium farms.

The above findings confirm the views of various economists that there is excessive pressure of human population on the farming as reflected by lower marginal value productivity of human labour.
on Indian farms. The study further showed that bullock labour is being kept to optimal level under no capital constraint by the farmers due to their social prestige. But actually, the farmers are facing the constraint of capital and hence, in view of high marginal return on inputs like manure-fertilizers and irrigation, it is desirable (in case the farmers are unable to get additional funds to be invested on the above inputs) to reduce the capital invested on bullock power (use it in other subsidiary occupation like marketing of produce on hire basis) and to increase the level of manure-fertilizers and irrigation. The surplus of family labour may be diverted to complementary, supplementary enterprises like dairy and poultry farming etc.

In summing up the results of regression analysis on the farms of various size groups under study, it can be concluded that the yield of wheat on the farms of almost all size group and all farms as a whole can significantly be oriented upward simply by reallocation of existing farm resources under capital constraints.