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(Research Article)

Estimation of Production Function for a Rice-Mill Industry

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Abstract

In the current globalised and severely competitive market, industrial firms are continuously striving for enhancing their productivities. For improving economic performance of firms, the study of relationship between input and output variables in production is inevitable. In the nineteenth and first half of twentieth century there was not much interest among firm management executives in production function analysis due to surplus availability of raw materials and conventional manufacturing practices. But in the contemporary world there is more number of products, companies, and increased competitive market scenario compelling quality products, cost effective production and efficient utilisation of raw material and energy resources. To obtain a comprehensive and clear picture of expenditure involved and profits earned through production in an industry, the analysis of various factors of production is essential. In this backdrop, this paper presents an empirical study carried out across 40 firms of a rice-mill industry cluster of Koppal in Karnataka state. Employing the empirical data obtained through researcher administered questionnaire, the relationship between various production inputs and output was modelled using Cobb Douglas production function. The assumptions in the Multiple Regression Analysis (MRA) adopted in this model are duly tested using SPSS software. The results of MRA revealed that the capital and energy inputs are significant while labour costs have insignificant influence with respect to the output. This finding establishes the need to focus on capital and energy inputs by this industry for enhancing their productivity leading to survival and growth in the long run.

Keywords: Rice-mill cluster, MRA, Returns to Scale, Cobb-Douglas Production Function.

1. Introduction

Production function is the mathematical modeling of relationship between tangible inputs and output of production in a company [1]. For establishing this relationship amongst input and output variables different types of standardized production functions are evolved such as Cobb Douglas production function, Leontief production function, and Constant Elasticity Substitution (CES) production function. Out of them, Cobb Douglas function has grabbed the attention of researchers, analysts and industrialists due to its unique features and benefits [2]. This production function precisely depicts many production processes (3). The Cobb Douglas production function (1) is in multiplicative form and is represented as:

$$Y = A \cdot L^{\alpha} \cdot K^{\beta} \qquad \text{...... (1)}$$

Where Y is the output and L, K are labour and capital inputs. The commendable qualities of this production function are:

- It enables the conversion of multiplicative form of production function to log-linear form as:
  $\log Y = \log A + \alpha \log L + \beta \log K$
- The degree of homogeneity can be observed by summing exponents. As a result, the important property of 'returns to scale' is found.
- The exponents represent the elasticity coefficients of output with respect to their corresponding input variables.
- The constants α and β depict the relative distributive share of inputs L and K.
- This production function will be zero at zero production costs.

Based on the original form of this production function, the current study employed initial investment in plant & machinery or capital (K), labor costs (L) as independent variables apart from energy cost (E) and material cost (M) which have appreciable share in total production costs (2).

In the current study involving a rice mill cluster; input investment (K) comprises land, infrastructure and machinery costs. Input labour costs (L) consists of wages of permanent and temporary workers. Input energy (E) costs involve electricity expenses and diesel use costs, but the biomass (rice husk) cost is excluded since this byproduct of rice processing

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is recycled as fuel to the boiler [3]. Input raw material (M) entails paddy costs, which has high correlation with output (4). Output (Y) encompasses production yield which is rice, expressed in terms of number of tons or monetary value [4].

2. Building a Production Function for Rice Mill Cluster

The aim of the present study is to find the relation between input variables and output variable in production activity of rice mill industry [5]. For this purpose, primary data regarding initial investment, production output, labour cost, energy expenses and raw material cost per month was collected from 40 units of Koppal city rice mills cluster, in Karnataka. The details of data collection are shown in table 1.

Table 1. Input and Output variables of Rice mill cluster

Rice mill no.	Production in no. of tones (Y)	Investment in INR (k)	Total employees salary/month (L)	Total energy used In Mj (E)	Cost of Bags (M)
1	1004.399996	200000000	242000	1026169.963	32175000
2	836.999997	29300000	186000	857453.292	27000000
3	836.999997	28900000	151000	1416550.939	28305000
4	836.999997	30200000	166000	974334.1176	29565000
5	1241.999996	46800000	182000	1137278.376	40185000
6	1004.399996	50500000	176000	954123.723	33435000
7	418.4999985	31100000	86000	665188.758	13500000
8	1241.999996	67900000	292000	1695878.44	41805000
9	418.4999985	30300000	86000	472917.7314	13185000
10	836.999997	34000000	232000	740818.323	27675000
11	1506.599995	48400000	222000	1624508.361	48240000
12	418.4999985	31100000	146000	531592.0596	14175000
13	2510.999991	57700000	272000	2507169.181	80370000
14	1004.399996	32200000	152000	951086.4624	32805000
15	502.1999982	31400000	261000	680109.3965	16065000
16	251.0999991	17600000	46000	31858.416	8370000
17	334.7999988	30600000	182000	371918.484	10935000
18	292.949999	32400000	66000	432513.018	9675000
19	836.999997	33600000	86000	817993.512	27315000
20	502.1999982	33700000	132000	607052.1366	16740000
21	502.1999982	32300000	157000	595012.689	16425000
22	1241.999996	32300000	162000	1288497.823	40500000
23	2008.799993	60300000	102000	3744069.26	64305000
24	418.4999985	45600000	192000	719297.2278	14490000
25	836.999997	33000000	141000	781570.188	27315000
26	3347.999988	1000000000	112000	3462586.085	107370000
27	292.949999	29000000	116000	387213.2712	9990000
28	502.1999982	25100000	276000	601155.954	17055000
29	836.999997	31200000	196000	855141.66	27135000
30	585.8999979	29200000	81000	616188.3516	20250000
31	585.8999979	33500000	332000	704074.95	19935000
32	209.2499993	18900000	46000	31858.416	7065000
33	1004.399996	24300000	126000	880209.909	33750000
34	418.4999985	19400000	61000	63716.832	7740000
35	1004.399996	29500000	132000	816208.2486	33120000
36	418.44999985	31100000	92000	544669.524	13815000
37	502.199982	31200000	106000	620069.49	16740000
38	585.8999979	31100000	86000	715081.6476	19305000
39	376.6499987	30800000	116000	494224.1136	12240000
40	334.7999988	30500000	136000	434267.3196	11565000

2.1 Methodology: For building a production function, the variables collected in the data were approximated to certain appropriate standard production function for instance Cobb Douglas production function [6]. Apart from other production functions like Leontief production function and CES production function, the Cobb Douglas production function is simpler and enables in easy conversion of function from algebraic form to natural log-linear form. The input and output variables Y, K, L, E and M from the data can be represented in Cobb Douglas production function in the following way.

$$Y = AK^{\alpha} L^{\beta} E^{\gamma} M^{\delta} \qquad \ldots\ldots (2)$$

Where:
Y = Total production output (in terms of no. of tonnes)
K = Capital input (the monetary value of all machinery, equipment, and buildings in terms of INR)
L = Labour input (in terms of labour costs in INR)
E = Energy input (Total energy in terms of Mega joules used)
M = Raw material costs (paddy cost in terms of INR)
A, α, β, γ and δ = parameters to be determined by regression analysis and they consequently assist in determining the relationship between the production variables.

In order to perform Multiple Regression Analysis (MRA), to find constant, beta values and to analyze the relationship between the variables, above equation is transformed to natural log-linear form as given below:

$$Ln(Y) = Ln(A) + \alpha Ln(K) + \beta Ln(L) + \gamma Ln(E) + \delta Ln(M) \quad .(3)$$

Those Ln(Y), Ln(K), Ln(L), Ln(E) and Ln(M) values are used for regression analysis. Initially, a trial run is made using the collected data. Subsequently, analyzing the results, the current model was rebuilt eliminating the insignificant input production variables which are discussed in the succeeding sections.

2.2 Returns to Scale: It is a property of production function that examines the changes in output subsequent to a proportional change in all the inputs (where all inputs increase by a constant proportion). If output increases by the same proportional change then that particular production function has constant returns to scale $(\alpha + \gamma = 1)$.

In other words, a production function exhibits constant returns to scale (CRS) if changing all input factors by a positive proportion has changing output by the same proportion. If output increases by less than that proportional change, then that production function is said to have decreasing returns to scale (DRS). Similarly, if output increases by more than that proportion, then increasing returns to scale (IRS) is said to exist.

Returns to scale will be increasing, if $\alpha + \gamma > 1$,
Returns to scale will be decreasing, if $\alpha + \gamma < 1$,
Returns to scale will be constant, if $\alpha + \gamma = 1$.

The beta values from table 3 were found to be 0.261 and 0.662, then returns to scale can be estimated as:

$$\alpha + \beta = 0.261 + 0.662 = 0.923 < 1$$

Since, sum of beta values are less than one (0.923<1), Decreasing Returns to Scale (DRS) is prevailing in the rice mills under study. This conveys a message that there is scope for improving Returns to Scale of rice mills, through energy efficient practices and effective employment of capital.

2.3 Validation of Assumptions of Multiple Regression Model:

2.3.1 Cumulative Probability plot of Residuals for the Koppal Rice Mill Cluster:

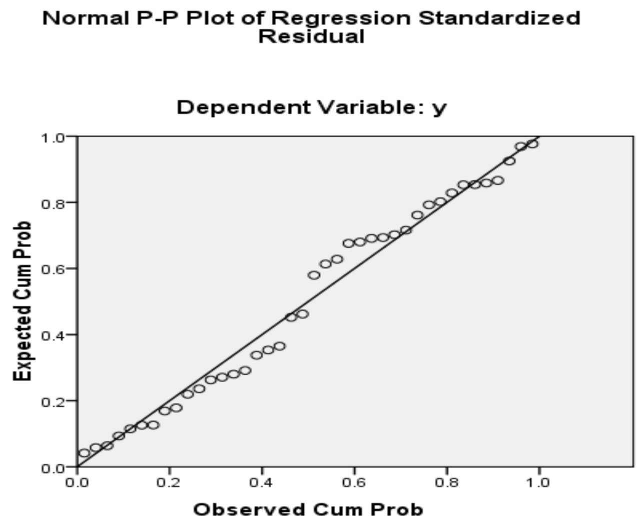

Figure 1. Cumulative Probability plot of Residuals for Koppal Rice mill cluster

The above Cumulative probability plot between expected and observed variables shows that the scatters of variables are close to the straight line. This leads to the conclusion that residuals approximately follow the normal distribution. Hence, the chosen model meets the validity requirement.

2.3.2 Residual plot for the Koppal Rice Mill Cluster: From Figure 2, the following properties are discussed.

- Linearity: The scatter of points in the Standardized residual versus Standardized Predicted value plot if found in a systematic way or in some particular order then the regression model will violate the linearity property. Therefore, the scattered points have to be in random manner. The above plot has residuals distributed in random manner, thus, chosen model possess Linearity property.
- Equality of Variance: For validating this assumption, the spread of residuals in the scatter plot should not have the increasing or decreasing tendency with the predicted values. From the above plot it may be observed that there is no increasing or decreasing tendency of spread of residuals with predicted values. Thus, the chosen model possess the Equality of Variance property.
- Locating Outliers: If any residuals present in +3σ or -3σ extreme lines, then the chosen model is said to have

Outliers. However, from the above plot all the residuals are found within ±3σ lines, so no outliers are present in the chosen model.

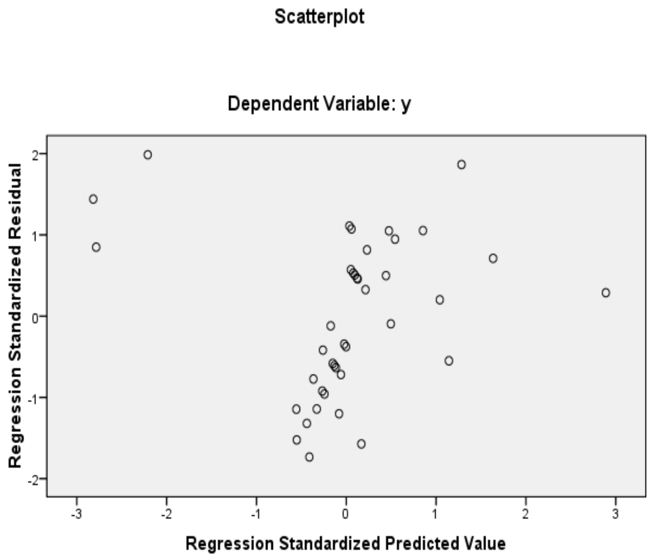

Figure 2. Residuals plot for Koppal Rice mill cluster

2.3.3 Partial Residual Plots:

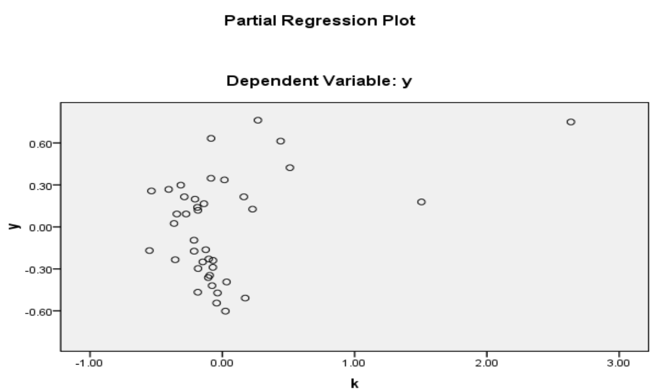

Figure 3. Partial Residual plot (Y versus K) for Koppal Rice mill cluster

From figure 3, The Partial Regression Plot of Output 'y' versus Capital investment 'k' shows scatter of residuals in random manner, Hence heteroskedasticity is not found. From figure 4, The Partial Regression Plot of Output 'y' versus Energy 'e' shows scatter of residuals in positive pattern, Hence heteroskedasticity was caused by variable energy 'e'.

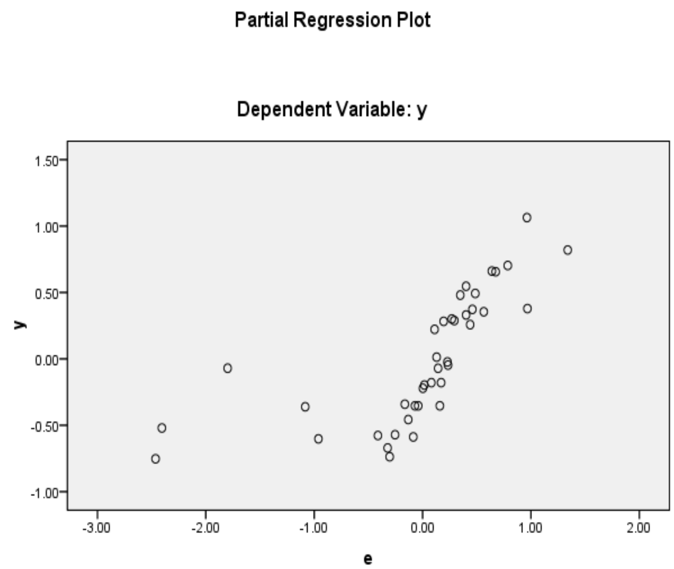

Figure 4. Partial Residual plot (Y versus E) for Koppal Rice mill cluster

3. Results of Multiple Regression Analysis

From the trial results with variables Y, K, L, E and M, it is observed that there was high significance (0.000) of variable raw material (M) with regards to output (Y) leading other variables insignificant. Hence, variable M is eliminated and again trial run of regression analysis was made using variables Y, K, L and E.

From the second trial result, the variable labor costs (L) turned as insignificant (0.873). Thus, variable L was expelled. Further regression analysis was made utilizing variables Y, K and E.

The result from those three variables holds good. As mentioned earlier, the output 'Y' in tonnes, the investment 'K' in INR, the energy 'E' in mega joules are used. Hence the required production function is-

$$Y = AK^{\alpha}E^{\gamma} \tag{4}$$

Table 2 provides Model summary of Production function model (with variables Y, K and E) and Table 3 provides Coefficients result table for Production function model (with variables Y, K and E)

Table 2. Model summary

Model Summary[b]										
Model	R	R Square	Adjusted R Square	Std.Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig.F Change	
1	0.838*	0.703	0.687	.35033	0.703	43.762	2	37	.000	1.874
a. Predictors:(constant), E, K										
b. Dependent variable: Y										

In the above model summary, the adjusted R square was 0.687. Thus, it may be concluded that the chosen independent variables (K and E) were capable of explaining the variation in the dependent variable (Output level) by 68.7% using this Production function.

The table 3 provides the collinearity statistics, significance levels, beta values, standard error and correlations of independent variables with respect to dependent variable.

Table 3. Coefficients result table

Coefficient[a]													
Model		Unstandarized coefficients		Standardized. coefficients	t	Sig.	95.0% confidence interval for B		Correlations			Collinearity statistics	
		B	Std. error	Beta			Lower bound	Upper bound	Zero order	Partial	Part	Tolerances	VIF
1	(cons-tant)	-3.488	1.470		-2.373	0.023	6.487	0.510					
	K	0.245	0.103	261	2.387	0.022	0.037	0.453	0.639	0.385	0.214	0.673	1.485
	E	0.427	0.071	662	6.058	0.000	0.284	0.570	0.811	0.706	0.543	0.673	1.485
a. Dependent variable :Y													

From the Coefficients result table, it is clear that chosen independent variables (K, E) are significant with respect to dependent variable (Y) as significance values are 0.022 and 0.00 (both values are lesser than 0.05). The model doesn't possess the multi-collinearity property because the Independent variables have Variance Inflation Factor (VIF) values which are less than 2 and tolerance values are greater than 0.01.

If the inputs are individually considered for regression with output, then regression of output Y with capital K results in the adjusted R square of 0.394, which means only 39.4% of the variation in output 'Y' is explained by the Investment values (K). Moreover, significance value was found to be 0.000 (highly significant). The regression of output Y with energy E gives rise to an adjusted R square of 0.647, meaning about 64.7% of variation in rice production level 'Y' is explained by the energy consumption values E. Again, significance value was found to be 0.000 (highly significant).

4. Conclusions

This paper aims to provide research evidence to the rice mill owners about the current situation of rice mill performance. The purpose of constructing this Production Function model is to uncover the relationship between Input and Output variables such that firm management could analyze the current state of their unit. This aids in varying the inputs accordingly to get desired output levels. The derived production function holds good for the Koppal Rice mill cluster. However, a generalized model for rice mill industry requires more research in other such clusters involving data from diverse geographical and technological clusters. In the present model, there is decreasing returns to scale (0.923<1) which indicates scope for further improvement in input utilization in this cluster.

Nomenclature

MRA: Multiple Regression Analysis
CES: Constant Elasticity Substitution
CRTS: Constant Returns to Scale
IRTS: Increased Returns to Scale
DRTS: Decreased Returns to Scale

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