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Factor demand and output supply of paddy: a normalized Cobb-Douglas profit function approach

[1]S. S. Thakare and [1]N. V. Shende

(Dr. Panjabrao Deshmukh Agriculture University, Akola)
[1]Assistant Professor, Shri Shivaji Agriculture College, Amravati
[2]Associate Professor, College of Agriculture, Nagpur

Corresponding Author's Email: drsandipthakare@gmail.com,drsandip_28thakare@rediffmail.com, nv_shende@yahoo.com, nv_shende@rediffmail.com

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In this study an attempt has been made to study the factor demand of output supply of paddy by using a normalized Cobb-Douglas profit function Approach. The output supply and factor demand are closely interlinked to each other. Therefore, any change in factor and product prices affect the factor demand and output supply simultaneously. The present study used cross sectional cum time series data of Vidarbha region of Maharashtra state for paddy crop for the ten years from 1999-00 to 2008-09 were collected from the Agricultural Prices and costs Scheme, Department of Agricultural Economics and Statistics, Dr. PDKV, Akola by keeping in view to study the change in factor and product prices, cost and returns and to estimate factor demand and output supply by using normalized Cobb-Douglas profit function. The study revealed that, the gross income from paddy increased at an annual rate of 5.83 per cent per annum. It may be attributed to both, the increase in output prices as well as increase in yield. The analysis of factor demand equation showed that the demand elasticities with respect to own prices had the expected negative sign indicating that the results were in accordance with the theory of demand. The effect of wage rate was more on bullock labour demand (-0.114), while the effect of bullock labour price on human demand was low (-0.071). This indicates the one way complementarity between bullock labour and human labour. The output supply equation revealed that among the fixed factor, capital was found to be somewhat effective in increasing the supply of paddy. The output supply elasticity with respect to capital was (0.221). Joint estimation of Cobb-Douglas profit function and factor demand equation by using Zellner's method shows that the profit function was decreased in prices of Labour, Fertilizer and seed. Among the variable factors, normalized wage rate in general had the highest negative impact on variable profit followed by seed price and bullock labour price.

Keywords: Paddy, factor demand, output supply, profit function

INTRODUCTION

The price of agricultural commodities and agricultural raw materials are the key factors in the price structure of an agrarian economy. Lower prices of output act as a deterrent in the utilization of inputs while higher output prices may bring about additional utilization of resources for maximization of profit whereas the rising input prices discourage input use and vice – versa. The decline in output supply raises food prices. The rapid increase in population and the increase in money income as a result of economic development create a strong pressure on demand which also leads to increase in food grain prices. These cause hardship to the consumers. This can be corrected only by a large and adequate supply of agricultural output and a greater attention is, therefore, required to be focused for matching the demand for food grains and agricultural commodities with the supply thereof. The rise in food grains prices should be sufficiently high not-only to counteract the rising cost of inputs but also to leave a rate of profit conductive for investment in agriculture and thereby accelerating supply of agricultural output. In this context, one needs detailed knowledge about the net effect of price and non-

price factors like factor and product prices, technology, irrigation, capital use, acreage etc. so that required adjustment needed in price and non-price factors could be worked out to attain the specific goals of prices, production and crop income.

Paddy is one of the important cereal in India which occupied 45.4 million hectares area with production of 99.2 million tones and productivity of 2186 kg ha^{-1} (Anonymous [a] 2009). In Maharashtra the area under rice during 2008-09 was 1.49 million hectares and production and productivity of rice were 2.24 million tones and 1491 kg ha^{-1} respectively, while in Vidarbha the area under rice cultivation was 7.32 lakh hectares with production of 5.62 lakh tones and productivity was 768 kg ha^{-1} (Anonymous [b]2009).

MATERIAL AND METHODS

The Agricultural Prices and Costs (APC) scheme under the guidance of government of Maharashtra provides valuable data about Agriculture in Maharashtra. The present study used cross sectional cum time series data of Vidarbha region for the paddy crop for the ten years i.e. from 1999-00 to 2008-09. Every year 100 farmers were selected for the present study. The scheme is involved in the collection of representative data on input use and yield and there upon estimation of cost of cultivation of principle crops grown in the region. Data is collected every year and for all the enterprises. Although, the sample for particular year are selected with respect to specified principle crop. The data were collected for all the crops grown on the sample holdings.

Index of input prices

The input price indices are composite indices of prices of individual items of inputs. The indices were constructed using the cost of cultivation data for the period of last ten years with average of first triennium ending as the base year. First, the price indices of inputs of seed, labour, bullock labour, fertilizer, farm yard manure, capital, pesticide and depreciation on implements were constructed.

The composite indices of input prices for Paddy crop were constructed as

$$\text{Index of Input Price} = \sum_{i=1}^{9} S_i \left(\frac{P_{it}}{P_{io}} \right)$$

Where, Si = average share of i^{th} input in total input cost. P_{it}/P_{io} is the price index of i^{th} input in the t^{th} year using average of first triennium as the base year, i=1stands for Human wage index, i=2 Bullock wage index, i=3 Fertilizer price index, i=4 FYM price index, i=5 seed price index i=6 Interest rate index, i=7 Pesticide expenditure index, i=8 Depreciation charges index, and i=9 Rental value of land index.

Profit function analysis

The theory of profit function, developed to helps in overcoming the problem of simultaneous equation bias, if present. Another distinct advantage of this approach over production function is that with the help of duality theorem (Shephard, 1953), the variable factor demand function and supply function of products can be derived directly from the estimated profit function. Econometric application of this production theory based on duality between production function and variable profit function is a breakthrough in the theory of production. Shepherd's Lemma (1953) applies equally to profit functions, which states that the partial derivative of profit function with respect to output and input prices give the supply and demand function, respectively.

Let the Cobb-Douglas production function with usual neo-classical properties be written as

$$Q = A\ N^{\alpha 1} B^{\alpha 2}\ X^{\alpha 3} F^{\alpha 4} S^{\alpha 5} K^{\beta 1} L^{\beta 2}\ U$$

Where, (Q) is output of crop, human labour (N), Bullock labour (B), chemical plant nutrients (X) , farm yard manure (F) and seed (S) are the variable input and capital input (K) and Land (L) are fixed input, and U is error term.

When working with profit function one has to choose functional forms which are homogenous of degree one in all prices, whereas this is not necessary for normalized profit function. The profit function formulation suggested by Lau and Yotopoulos (1972) enables us to derive factor demand as a function of normalized input rates and the quantities of fixed inputs.

Invoking the theory of profit function, the normalized profit function for the above production function can be written as below.

$$\frac{\pi}{P} = A^* (w/P)^{\alpha_1^*} (b/P)^{\alpha_2^*} (r/P)^{\alpha_3^*} (m/P)^{\alpha_4^*} (s/P)^{\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*} U$$

OR

$$\pi^* = A^* w^{*\alpha_1^*} b^{*\alpha_2^*} r^{*\alpha_3^*} m^{*\alpha_4^*} S^{*\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*} U \text{ ---------- (1)}$$

Where π* = π/p =normalized profit or output price (UOP) profit, w* is the normalized wage rate, b* is the normalized bullock labour price, r* is the normalized fertilizer price, m* is the normalized farm yard manure price and s* is the normalized seed price.

From the estimated parameters of normalized profit function, the production elasticities of inputs and intercept were derived.

Factor demand function

Shepherd's Lemma (1953) asserts that the first order negative derivative of the normalized profit equation with

respect to normalized wage rate, bullock labour price, fertilizer price, farm yard manure price and seed price respectively, gives the derived factor demand function. The factor demand equation on case of Cobb-Douglas type normalized profit function was given as

i). Human labour demand equation

$-\frac{\partial\pi^*}{\partial w^*}$ = -$\alpha_1^*\left(\frac{\pi^*}{w^*}\right)$ = N or $\frac{w^*N}{\pi^*}$ = -α_1^* ------- (a)

i). Bullock labour demand equation

$-\frac{\partial\pi^*}{\partial b^*} = -\alpha_2^*\left(\frac{\pi^*}{b^*}\right)$ = B or $\frac{b^*B}{\pi^*}$ = -α_2^* ----- (b)

i). Fertilizer demand equation

$-\frac{\partial\pi^*}{\partial r^*}$ = -$\alpha_3^*\left(\frac{\pi^*}{r^*}\right)$ = X or $\frac{r^*X}{\pi^*}$ = -α_3^* -------(c)

ii). Farm yard manure demand equation

$-\frac{\partial\pi^*}{\partial f^*}$ = -$\alpha_4^*\left(\frac{\pi^*}{f^*}\right)$ = F or $\frac{f^*F}{\pi^*}$ = -α_4^* ----- (d)

iii). Seed demand equation

$-\frac{\partial\pi^*}{\partial s^*}$ = -$\alpha_5^*\left(\frac{\pi^*}{s^*}\right)$ = S or $\frac{s^*S}{\pi^*}$ = -α_5^* ----- (e)

Substituting π* from identity (1) into (a) to (e), the demand equation can be written as :

Labour demand equation

$N = -\alpha_1^* A^* (w^*)^{\alpha_1^*-1} b^{*\alpha_2^*} r^{*\alpha_3^*} m^{*\alpha_4^*} s^{*\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*}$

Bullock labour demand equation

$B = -\alpha_2^* A^* w^{*\alpha_1^*} (b^*)^{\alpha_2^*-1} r^{*\alpha_3^*} m^{*\alpha_4^*} s^{*\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*}$

Fertilizer demand equation

$X = -\alpha_3^* A^* w^{*\alpha_1^*} b^{*\alpha_2^*} (r^*)^{\alpha_3^*-1} m^{*\alpha_4^*} s^{*\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*}$

Farm yard manure demand equation

$F = -\alpha_4^* A^* w^{*\alpha_1^*} b^{*\alpha_2^*} r^{*\alpha_3^*} (m^*)^{\alpha_4^*-1} s^{*\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*}$

Seed demand equation

$S = -\alpha_5^* A^* w^{*\alpha_1^*} b^{*\alpha_2^*} r^{*\alpha_3^*} m^{*\alpha_4^*} (s^*)^{\alpha_5^*-1} K^{\beta_1^*} L^{\beta_2^*}$

Output supply function

Shepherd's Lemma (1953) asserts that first order derivative of profit function with respect to output price gives output supply function.

$\frac{\partial\pi}{\partial P}$ = θ $\left(\frac{\pi}{P}\right)$ = Q or $\frac{P.Q}{\pi}$ = θ

The output supply function in the form of Cobb-Douglas production function was written as

$Q = A\,\theta P^{\theta-1} w^{*\alpha_1^*} b^{*\alpha_2^*} r^{*\alpha_3^*} m^{*\alpha_4^*} s^{*\alpha_5^*} K^{\beta_1^*} L^{\beta_2^*}$

The above equation was giving the output supply with respect to output prices, wage rate, bullock labour price, fertilizer price, farm yard manure price, seed price and price of capital input.

Joint estimation of Cobb-Douglas profit functions and factor demand

The normalized profit function and factor demand functions for human labour, bullock labour, fertilizer farmyard manure and seed were jointly estimated using Zellner's method (1962) for estimating 'Seemingly Unrelated Regression Equation (SURE)' by imposing the restriction that α^{1*}, α^{2*}, α^{3*}, α^{4*} and α^{5*} are equal in both the normalized profit function and relevant factor demand equations.

By using SURE method the coefficient were estimated as

$$\hat{\alpha}_{SURE} = (X' V^{-1} X)^{-1} X' V^{-1} Y$$

Where, X is independent variable and Y is dependent variable

$V = \sum \otimes I_N$

Where, $\sum$ representing the covariance of residual between the equations, $\otimes$ is the Kronecker product and I_N is the identity matrix of number of observations.

RESULTS AND DISCUSSION

The examination of change in factor and product prices, cost and returns of paddy is important for designing effective price policy. This has got important implication on income distribution, saving and investment and hence on further growth prospect of agricultural sector and economy at large.

Changes in factor and product prices

Transformation of agriculture from subsistence to profitable farm business is a techno-organizational process, the success of which largely depends on the relative prices of various inputs and outputs. Therefore, it would be interest to examine the changes in prices of inputs and outputs. The rate of growth of average prices and output prices for paddy are presented in table 1.

Table 1 reveals that price of all inputs showed an increasing trend during the period 1999-00 to 2008-09. The compound growth rate of input prices for paddy were highest for bullock labour prices (6.27 per cent per annum) followed by prices of Fertilizer (4.27 per cent per annum). The per cent growth rates in wage rate and seed prices were observed to be 3.17 per cent and 2.27 per cent per annum respectively.

The output prices increased at an annual compound rate of 5.74 per cent per annum for paddy during the period under study.

Parity between prices received for products and prices paid for inputs

Parity prices for farm products are those prices which would give the same purchasing power to the producer as prevailed in the base year. In order to examine the parity between the prices received for output and prices paid for agricultural inputs, parity indices were computed by deflating output price indices by the input price indices.

Table 2 presents input-output price indices for paddy crop. It is evident from the table that between 1999-00 to

Table 1: Growth rate of factor and product prices (1999-00 to 2008-09)

Items	Compound growth rate (per cent)
Input Prices	
Wage rate	3.17**
Bullock labour price	6.27***
Farm yard manure price	2.76
Fertilizer price	4.27**
Seed price	2.27**
Output Price	**5.74*** **

(***, **,*denotes significant at 1%, 5% and 10% level)

Table 2: Parity between output price index and input price index for paddy
(Base year- Average of Triennium Ending – 1999-00 to 2001-02)

Years	Input price Index	Output price Index	Parity Index
1999-00	98.52	104.00	105.56
2000-01	97.73	98.11	100.39
2001-02	105.46	97.89	92.82
2002-03	109.57	102.90	93.91
2003-04	120.47	109.30	90.72
2004-05	108.63	109.30	100.62
2005-06	145.91	115.86	79.40
2006-07	115.46	126.94	109.94
2007-08	125.50	145.02	115.56
2008-09	129.46	190.30	147.00

Parity index = (Output price index/ Input price Index) x 100

Table 3: Cost of Production of paddy

Years	Cost C per qt. At current price (₹)	Input price index	Cost C per qt. At constant price (₹)	Yield per hectare (qt.)	MSP at constant prices
1999-00	614.60	98.52	623.83	22.83	520.00
2000-01	732.86	97.73	749.88	19.59	513.00
2001-02	608.23	105.46	576.74	26.30	520.80
2002-03	618.39	109.57	564.38	28.43	492.80
2003-04	626.60	120.47	520.13	29.06	464.00
2004-05	724.74	108.63	667.17	21.26	454.30
2005-06	658.22	145.91	451.11	33.80	444.00
2006-07	715.01	115.46	619.27	24.15	439.20
2007-08	696.98	125.50	555.36	27.32	438.75
2008-09	1014.54	129.46	783.67	19.69	554.40
CGR (%)	3.26**		-0.07		-1.03

(***, **, *denotes significant at 1%, 5% and 10% level)

2008-09, the input price index for paddy increased by 29 per cent, while the increase in output price was 90 per cent. Further, the output-input price parity were decreased during year 2001-02 to 2003-04 and in year 2005-06, increased in the subsequent years, indicating thereby up to the year 2001-02 to 2003-04, and in year 2005-06, the output price were lower than input price and term of trade was unfavourable for paddy growers. However, the term of trade was favourable for the paddy growers afterward.

Changes in costs

The cost of production per unit of output depends on the per hectare cost of cultivation and yield. For computing the cost of production at constant factor prices, the unit cost of production at current prices was deflated by an input price index series taking initial triennium ending average as the base year.

The cost of production at current and constant prices for paddy is presented in Table 3. The Table revealed

Table 4: Change in cost and returns from paddy

Years	Input price Index	Output price Index	Gross income per ha.	Cost C per ha.	Net income per ha.	Output-cost ratio
1999-00	98.52	104.00	14727.78	14031.21	696.56	1.050
2000-01	97.73	98.11	12098.35	14357.06	-2258.71	0.843
2001-02	105.46	97.89	15781.00	15998.12	-217.12	0.986
2002-03	109.57	102.90	18096.59	17579.02	517.58	1.029
2003-04	120.47	109.30	18548.51	18208.86	339.65	1.019
2004-05	108.63	109.30	14563.37	15404.54	-841.17	0.945
2005-06	145.91	115.86	23049.62	22246.06	803.56	1.036
2006-07	115.46	126.94	18254.04	17267.53	986.50	1.057
2007-08	125.50	145.02	23174.57	19043.79	4130.78	1.217
2008-09	129.46	190.30	21961.43	19976.26	1985.17	1.099
CGR (%)	3.34***	3.68***	5.83***	3.75**		

(***, **, *denotes significant at 1%, 5% and 10% level)

that, the increase in yield from 1999-00 to 2005-06, resulted in substantial fall in the cost per unit of output of paddy at current prices. Again in years 2006-07, a fall in yield per hectare brought about a further sharp escalation in per unit cost of output.

The examination of cost of production at constant price did not indicate any clear trend, neither upward nor downward. The remaining variation in unit cost could be explained in term of yield fluctuation over the year. It was further observed that, whenever there was any improvement in the yield, it brought down the cost of production per quintal.

The average cost of production varied from ₹ 608.23 with an average yield of 26.30 quintal in the year 2001-02 to ₹ 1014.54 per quintal with an average yield 19.69 quintal in the year 2008-09. This clearly indicates that technological breakthrough in the cultivation of paddy has not compensated the cost push inflation. Therefore per unit cost of output did not decline over time.

It has been hypothesized that with the improvement in productivity of crops the production function must shift upward and cost of production at constant prices must decline. The analysis revealed that the cost of production did not decline. Thus it can be concluded that the technological development in paddy has not shown its impact in reducing the cost of production in Vidarbha.

Changes in returns

The data on cost and returns from paddy at different point of time are presented in Table 4. The result reveals the gross income from paddy increased at an annual rate of 5.83 per cent per annum between 1999-00 to 2008-09. The increased in gross income may be attributed to both increase in output price as well as increase in yield of main product and by product.

However, the rate of increase in cost of cultivation per hectare was 3.75 per cent. This resulted in an improvement in the net income per hectare of paddy crop over the years. This was further reflected by output-cost ratio, which increased from 1.050 in 1999-00 to 1.099 in 2008-09. However, in the year 2000-01 to 2001-02 and 2004-05, the output-cost ratio was not very impressive mainly due to low productivity per unit area while in 2007-08, the output-cost ratio was increased i.e. 1.217.

It is reveals from the table that the input price index for paddy crop increased at an annual compound growth rate of 3.34 per cent per annum while the output price index increased at an annual rate of only 3.68 per cent per annum.

Factor demand and output supply

A system of factor demand equations were derived from the estimated normalized profit function. The results of human labour, bullock labour, fertilizer, farm yard manure and seed demand equation for selected crops are presented below and the degree of responsiveness of input and output price movements on the use of inputs are discussed. This information is of crucial importance in the formulation of effective price policies for crops to reach specified production goals.

Table 5 revealed that demand elasticities with respect to own price had anticipated negative signs indicating that the results were in accordance with the theory of demand. The absolute value of own price elasticity of human labour and seed were greater than unity indicating there by an elastic response of input utilization to their own price.

One per cent increase in own price, holding other prices constant, will reduce human labour employment at 1.079 per cent and seed demand 1.616 per cent in paddy crop.

A negative sign of cross price elasticity with respect to the price of other variable inputs shows that the pair is

Table 5: Input demand and Output supply for paddy crop

Variables	Human Labour	Bullock Labour	Fertilizer	F.Y.M.	Seed	Output Supply
Intercept	0.216	-1.182	-0.393	0.243	0.830	0.246
Output price	0.993	1.064	-0.083	0.576	0.999	-0.756
Wage rate	-1.079	-0.114	-0.762	-0.597	0.395	0.322
Bullock labour price	-0.071	-0.691	-0.104	0.066	0.050	-0.126
Fertilizer price	0.026	-0.035	0.200	0.049	0.033	0.010
F.Y.M. price	0.007	0.043	-0.041	-0.168	0.026	0.196
Seed Price	0.080	0.168	0.180	-0.153	-1.616	0.142
Capital	0.060	-0.330	0.626	0.446	0.148	0.221
Land	-0.016	-0.105	-0.016	-0.220	-0.034	0.019

complement and a positive sign is an indicator of substitutive relationship. However, the positive sign of cross price elasticity with respect to quantities of fixed inputs indicates complementarity and negative sign indicates substitutive relationship.

The effect of wage rate was more on bullock labour demand (-0.114), while the effect of bullock labour price on human labour demand was low (-0.071). This indicates the one way complementarity between human labour and bullock labour. Obviously, without human labour, bullock labour cannot be used, where as the reverse is not true. The demand for all input responded positively to increase in output price for paddy crop. (Shende and Shinde 2010 reported that there was a complementarity between bullock labour and human labour for soybean in Vidarbha)

The output supply equation Vidarbha region for paddy crop was derived from the estimated profit function. The output supply equation given in table 5 gives the estimated of the responses of own output price, variable prices and fixed factors on output supply of paddy crop.

It can be observed from the study that own prices had responded positively to the output price, except bullock labour price. The elasticity with respect to bullock labour price for paddy was -0.126 resulted that a 1 per cent increase in bullock price was associated with about 0.126 per cent decline in crop output. Among the variable factors, human wage rate, fertilizer price, farm yard manure price and seed price had positive impact on the supply of paddy, however, among the fixed factor capital was found to be effective in increasing the supply of paddy. Capital input had positive impact (0.221) on the supply of paddy.

Joint estimation of the normalized profit functions and factor share for variable inputs

Lau and Yotopoulas (1972) pointed out that due to the presence of common parameters in profit and factor demand equation; they should be estimated jointly imposing the restriction that common parameters in both equations are equal. The five equations - UOP profit function, human labour, bullock labour, fertilizer, farm yard manure and seed demand functions were estimated jointly using Zellner's method (1962) for estimating 'Seemingly Unrelated Regression Equation (SURE)' by imposing appropriate restrictions.

As expected, the profit function was decreased in prices of Labour, Fertilizer and seed. Among the variable factors, normalized wage rate in general had the highest negative impact on variable profit followed by seed price and bullock labour price.

From this study it can be concluded that the, gross income from paddy increased at an annual rate of 5.83 per cent per annum. It may be attributed to both, the increase in output prices as well as increase in yield. The analysis of factor demand equation showed that the demand elasticities with respect to own prices had the expected negative sign indicating that the results were in accordance with the theory of demand and finally the study shows the complementarity between Human Labour and Bullock Labour in Paddy Cultivation.

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