Agricultural Economics Research Review 2018, 31 (Conference Number), 139-145
DOI: 10.5958/0974-0279.2018.00029.0

An econometric analysis of optimality for sustainable paddy production in India

Binita Kumari*, B S Chandel and Priyanka Lal

ICAR-National Dairy Research Institute, Karnal-132001, Haryana, India

Abstract The optimal level of production inputs ensures maximum returns to farmers and reduces the adverse effects of excessive use of inputs like fertilizers and pesticides on the environment. In India, paddy has the highest use of major inputs besides being labour intensive. This paper focuses on this crop and finds that, at national level, most of the inputs are used below optimum, and their usage can be increased to attain profit maximising yield, about 17% higher than the existing yield. However, across states, existing use of resources is different than that at the national level. In Punjab, Haryana and Tamil Nadu the use of almost all inputs is more than optimum. Seed that accounts for 8.6% of the cost of cultivation is overused in major rice growing states, namely Assam, West Bengal, and Chattisgarh, while fertilizer use is sub-optimal except in Chattisgarh. Human and animal labour together account for about 80% of the total cost, and are found to be overused in most states. These results indicate pathways for states that can be followed to attain optimality. Overall, the optimum level of input use ensures 8.5% higher farm profits.

Keywords Paddy, Optimal input use, Profit, India

JEL classification C30, C33, C51, Q01, Q21

1 Introduction

India is the second largest producer of paddy (with a production of 109.7 million tonnes in 2017). Paddy is a tropical crop and flourishes well in hot and humid climate. It is mainly grown as a rainfed crop in areas that receive heavy rainfall. That is why it is fundamentally a rainy season crop accounting for 91% of the total area under its cultivation. In some states like West Bengal, Assam and Odisha, it is also cultivated in winters because of favourable agro-climatic conditions. The productivity of Rabi paddy is also higher (Prasad 1999).

Rice is the staple food in India. It is important not only for consumers but for producers too as it is one of the principal crops grown throughout the country. It is necessary for this crop to be profitable in order to keep farmers engaged in its cultivation. Some farmers aim to have higher production even at higher input cost; mainly in the states that have established procurement system, while others strive to achieve maximum profit per unit of inputs used. In the process of achieving high production, farmers neglect the long-run consequences. For example, overuse of fertilisers has not only resulted in an increased cost of cultivation but has also contaminated groundwater and degraded soils. Thus, the inefficient use of such inputs has social costs and leads to sustainability problems that bear the opportunity costs. Based on ecological considerations, there is no reason why states like Punjab and Haryana should grow paddy on a large scale; rice is a water-intensive crop and these states are facing rapid depletion of groundwater (Chaudhary & Harrington 1993; Haque 2006). But, as the cost, yield, and prices suit to farmers' objectives, they indulge in paddy cultivation. Therefore, for a sustainable enterprise, the farmers should try to maximise their farm returns by allocating the resources in an efficient manner.

*Corresponding author: b.binitakumari@gmail.com

The widespread cultivation of the crop has put a heavy demand on agricultural inputs, especially seed, fertilizer and human labour. Paddy accounted for 29.3% (7.27 million tonnes) of total fertilizer consumption in 2011-12 (GoI 2016 [a]). Calculated on the basis of treated area, the fertilizer use in irrigated paddy (203 kg/ha) was more than double than in rainfed paddy (119 kg/ha). It may be noted that the fertilizer treated area is about 86% of the total area under paddy. The average per-hectare use of fertilizers in paddy was 174.18 kg (105.8 kg/ha N, 46.7 kg/ha P_2O_5 and 21.7 kg/ha K_2O) in 2011-12. The share of farm yard manure (FYM) used in paddy out of its total consumption in all crops is higher as compared to share of chemical fertilizers used in the crop's cultivation. The quantity of FYM used in paddy was 45.80 million tonnes, 34% of the total FYM used on all crops. The average per-hectare use of FYM in paddy was 33.57 quintals of the treated area and as a matter of fact, the treated area was as low as 28%. In the present study, an attempt has been made to determine the optimum levels of inputs use resulting in an output that maximises profit per hectare.

2 Data and method

2.1 Method

The econometric applications of duality between production function and profit function represent a major step towards generating empirical estimates of optimum output supply and input demand at profit maximization. In economic theory, profit function is defined as maximum profit that can be obtained at given input and output prices. Duality approach is preferred to be used as it overcomes the problem of solving first order condition by directly specifying maximum profit function rather than production function. By the duality approach, the assumption of profit maximisation and competitive market are assured to derive input demand and output supply equations. These equations are then used to determine the optimum level of output supply and input demands. The paper applies the same approach to derive output supply and input demand functions using normalised restricted translog profit function of the following form:

$$\ln\pi^{*'} = \alpha_0 + \sum_{i=1}^{5}\alpha_i \ln r_i + \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5}\gamma_{ij}\ln r_i \ln r_j$$

$$+\sum_{k=1}^{3}\beta_k \ln Z_k + \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\theta_{kl}\ln Z_k \ln Z_l$$

$$+\sum_{i=1}^{5}\sum_{k=1}^{3}\delta_{ik}\ln r_i \ln Z_k + \xi_i$$

Kumar (2005) has done similar study in case of milk using quadratic functional form while Mailena et al. (2013) used translog functional form for their study on rice production. Translog function is chosen because of its advantage over Cobb Douglas function as cited in Sidhu & Baanante (1981) and Chand (1986). This is considered to be more flexible and at the same time gives second-order approximation of the variables. In the function, $\pi^{*'}$ is the restricted profit normalised by output price and is estimated by deducting the cost of variable inputs from the gross revenue. The gross revenue is the sum of the values of main and by-products. The inputs included in the study are seed, fertilizer, manure, human labour and animal labour. The prices of inputs were normalised (r_i) by the output price. The normalisation reduces the function by one variable and the homogeneity constraint is automatically satisfied. There is one fixed factor i.e. working capital (Z_1) and two state shifters i.e. the proportion of gross cropped area under rice (Z_2) and irrigated area (Z_3). Since the input-output data on paddy cultivation have been taken per hectare basis for each state, the inclusion of latter two variables i.e. the proportion of gross cropped area under rice (Z_2) and irrigated area (Z_3), besides the prices is necessary to scale up the estimation of parameters at the aggregate level or the state level. All the values are taken in natural logarithmic form except the working capital and state shifters. There ξ_i is the error term. The parameters α_0, α_i, γ_{ij}, δ_{ik}, β_k and θ_{kl} are estimated and the subscripts 'i' & 'j' stands for prices of inputs (i= 1..j…5), 'z_k' stands for fixed factors and the state shifters when k=1, it is the working capital and k=2 and 3 are the shifters Z_2 and Z_3, respectively.

The partial derivatives of the log linear translog profit function, as defined earlier, with respect to log value of normalised input price yields the input share equations as given below:

$$S_i = \frac{\partial \ln \pi^{*'}}{\partial \ln r_i} = -\frac{P_i X_i}{\pi^*} = -si = \alpha_i + \sum_{j=1}^{5}\gamma_{ij}\ln r_j + \sum_{k=1}^{3}\delta_{ik}\ln Z_k$$

$$S_y = \frac{P_y Y}{\pi^*} = 1 + \sum \frac{\partial \ln \pi^{*'}}{\partial \ln r_i} = 1 - \alpha_i + \sum_{j=1}^{5} \gamma_{ij} \ln r_j + \sum_{k=1}^{3} \delta_{ik} \ln Z_k$$

Where, S_i is the negative share value of the i^{th} input and S_Y is the positive share value of output in the profit. Since the input and output shares form a singular system of equations (by definition ($S_y - \Sigma S_i = 1$)), one of the share equations i.e., the output share equation has been dropped. The remaining variable input share equations and the profit function are estimated jointly using Zellner's Seemingly Unrelated Regression Equation (SURE) procedure (Zellner 1962). Since the five input share equations are derived from the same normalised translog profit function, 45 linear equality parametric restrictions are imposed along with 10 symmetry constraints. The validity of imposed fifty-five joint null hypotheses is tested using F-value statistic with asymptotic properties as suggested by Theil (1971) at 55 number of restrictions (m) and 420 (n-k) degrees of freedom where 'n' is the total number of observations and 'k' is the number of parameters estimated in unrestricted function including the intercept.

To generate a system of demand functions for inputs, the negative of the first order partial derivatives of the normalised profit function with respect to normalised input prices $\left(-\frac{\partial \pi^{*'}}{\partial r_i} = X_i\right)$ was is taken following Hotelling's Lemma.

Factor demand function:

$$X_i = \frac{\pi^*}{S_i}\left[\alpha_i + \sum_{i=1}^{5} \gamma_{ij} \ln r_j + \sum_{k=1}^{3} \delta_{ik} \ln Z_k\right]$$

Output supply function is estimated by the residual method i.e. $Y = \pi^{*'} - \Sigma r_i X_i$; where X_i are the demand equations of i^{th} input and r_i were the normalized price of the same input. Putting the average values of various explanatory variables in the input demand functions, the optimum level of input usage at maximum profit was determined both for all India and states level. By comparing the existing use of each input with its optimum level in all individual states, the states are categorised into below optimum and above optimum use of resources.

2.2 Data

State-level time series data on the output produced and inputs used in paddy cultivation are taken from various reports of Comprehensive Scheme for the cost of cultivation of Principal crops, prepared by the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India (GoI various years [b]). A balanced panel having time series observations for five years from 2009 to 2013 across seventeen major paddy growing states is used to estimate profit, output supply, and input demand functions. Only those states are retained in the model that have information on the cost of cultivation of paddy throughout five years (2009-13). The geometric mean is taken for various components in order to overcome the problem of outliers.

3 Results and discussion

The average yield (2009-13) at the national level was 35.81 quintals while the average price received by farmers was Rs. 1,174.07 per quintal (table 1). With a total variable cost of Rs. 18,894.39 per hectare, the gross income obtained solely from paddy cultivation was Rs. 42,052.39 per hectare. The main by-products of paddy are straw, husk or hull, and rice bran which brings revenue of Rs. 3,413.96 per hectare. Among all inputs, the cost of human labour accounted for more than half of the total variable costs, showing that paddy is a labour intensive crop; while the share of variable cost in total cost is 57.23%. The structure of costs and returns in the top three states are, also, presented in table 1. Most of the components of cost show a similar trend but, in the case of Punjab, the total variable cost accounted for only 35.94%, which is the lowest among selected states. A higher proportion of the fixed cost is incurred in Punjab due to mechanisation of agriculture and less dependence on human labour and animal labour for paddy cultivation.

The estimates of the SURE model are presented in table 2. These parameter estimates are used to find out the optimum level of input used in paddy cultivation.

The optimum levels for seed, fertiliser, manure, human labour and animal labour for one hectare of paddy cultivation are 79.81 kg, 174.18 kg, 44.84 quintal, 808.83 man days and 23.48 animal labours, respectively, and at these level the optimum yield is 41.89 quintals and maximum profit Rs. 30,439.98 per hectare. Compared to the actual use of inputs, the use of all the inputs other than animal labour was lower than optimum level (table 3).

Table 1. Average cost of production and net returns from paddy cultivation per hectare, 2009-13 (Rs. per hectare)

Item	States			
	India	Tamil Nadu	Punjab	Andhra Pradesh
Yield (quintal)	35.81	99.22	63.23	54.98
Price (Rs./qtl)	1,174.07	1,203.60	1,230.71	1,163.45
Revenue from main crop	42,052.39	1,19,420.00	77,825.15	63,970.86
Revenue from by- product (straw, husk, bran)	3,413.96	4,131.61	898.96	3,852.67
Gross revenue	45,466.35	1,23,551.70	78,724.12	67,823.54
Variable cost				
Seed	1,622.91	4,573.53	1,344.26	1,818.89
	(8.58)	(14.58)	(7.98)	(7.98)
Fertiliser	2,106.66	4,762.98	3,225.38	4,287.06
	(11.14)	(15.19)	(19.14)	(19.14)
Manure	126.79	1,590.16	267.94	590.59
	(0.67)	(3.46)	(1.59)	(1.59)
Human labour	14,149.04	20,092.64	11,930.69	20,592.9
	(74.88)	(64.08)	(70.83)	(70.83)
Animal labour	888.97	335.04	74.53	642.99
	(4.70)	(1.06)	(0.44)	(0.44)
Total variable cost	18,894.39	31,354.37	16,842.81	27,932.44
	(57.23)	(55.89)	(35.94)	(68.35)
Total fixed cost	14,120.30	14,513.86	30,012.64	22,038.92
	(42.76)	(44.10)	(64.05)	(31.64)
Total cost	33,014.69	45,868.23	46,855.44	49,971.36
Net returns	12,451.66	77,683.23	31,868.67	17,852.18

Source: Authors' calculations based on GoI various years [b].
Note: Figures in parentheses are the percentage of input cost in their respective totals.

Table 2. Parameter estimates of normalised profit and factor share functions

	Interaction coefficients with normalised price (Rs.) of						Capital	Ratio w.r.t. GCA	
	Intercept	Seed (Rs./kg)	Fertilizer (Rs./kg)	Manure (Rs./tonne)	HL (Rs./hr)	AL (Rs./hr)	(Rs)	Irrigated area	Paddy area
Normalised profit	-17.8597	-1.2271*	-0.7070	-0.0171	-9.7925*	-1.8143	4.7442	14.7523**	-8.2470*
function	(46.0447)	(0.5920)	(0.5291)	(0.2630)	(5.1539)	(1.9560)	(9.9669)	(4.9533)	(4.0184)
Seed share	-1.2271*	-0.0259	0.0022	-0.0013	-0.0957	-0.0109	0.1299*	0.0083	-0.0075
function	(0.5920)	(0.0180)	(0.0179)	(0.0044)	(0.0522)	(0.0229)	(0.0642)	(0.0287)	(0.0209)
Fertilizer	-0.7070	0.0022	-0.1483**	-0.0008	-0.0738	0.0247	0.0706	-0.0509	0.0413*
share function	(0.5291)	(0.0179)	(0.0453)	(0.0041)	(0.0495)	(0.0264)	(0.0571)	(0.0272)	(0.0215)
Manure share	-0.0171	-0.0013	-0.0008	-0.0019	0.0112	0.0012	0.0009	0.0329	0.0010
function	(0.2630)	(0.0044)	(0.0041)	(0.0025)	(0.0291)	(0.0112)	(0.0290)	(0.0175)	(0.0135)
HL share	-9.7925	-0.0957	-0.0738	0.0112	-0.8037	-0.1398	1.0396	0.4932*	-0.3297
function	(5.1539)	(0.0522)	(0.0495)	(0.0291)	(0.4988)	(0.1826)	(0.5701)	(0.2308)	(0.1772)
AL share	-1.8143	-0.0109	0.0247	0.0012	-0.1398	-0.0818	0.2119	0.2595**	-0.1249
function	(1.9560)	(0.0229)	(0.0264)	(0.0112)	(0.1826)	(0.0745)	(0.2163)	(0.0877)	(0.0674)

Source: Authors' calculations.
Notes: Figures in the parentheses are the standard errors.*, ** significant at 5 and 1% level, respectively. w.r.t = with respect to. GCA= gross cropped area. HL= human labour. AL= animal labour.

Table 3. Estimates of actual and optimum profit, yield and inputs at national level (Per hectare)

	Variable inputs					Profit (Rs.)	Yield (qtl)
	Seed (kg)	Fertiliser (kg)	Manure (qtl)	Human Labour (mandays)	Animal Labour (animal days)		
Optimum level	79.50	174.18	44.84	808.83	23.48	30,439.98	41.89
Actual input use							
Average	62.77	112.39	4.81	684.90	20.23	28,063.63	35.81
Minimum	7.48	11.66	0.00001	353.46	0.44	500.17	16.09
Maximum	113.98	290.49	45.77	1,385.36	205.03	94,117.10	67.97

Source: Authors' calculations based on GoI various years [b].

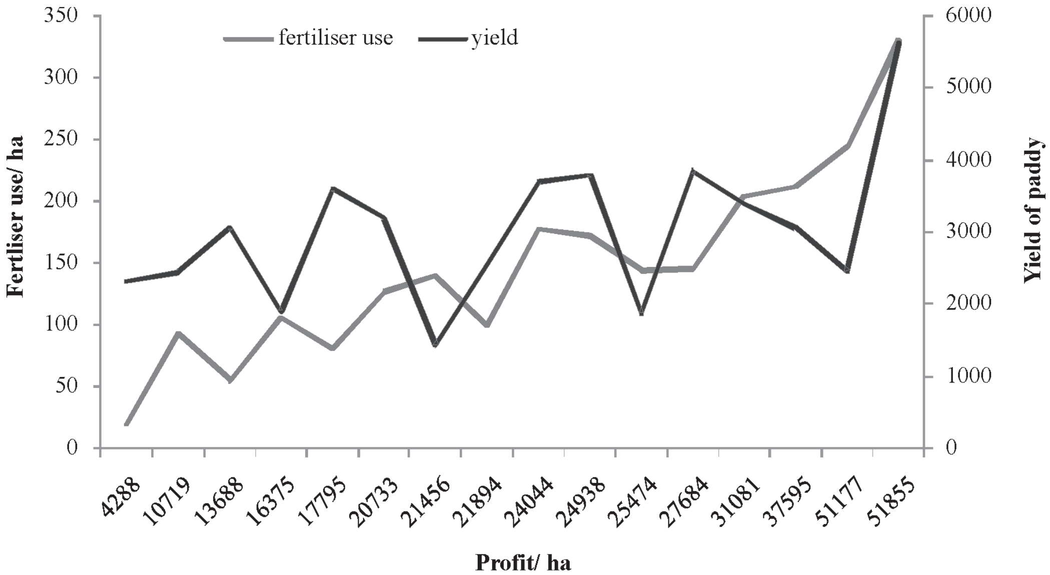

Figure 1. Trend among optimum levels of profit, yield and fertilizer use in paddy
Source: Authors' calculations based on GoI various years [b].

As it is evident from table 3, most of the inputs are used sub-optimally. On an average, an increase of all the input use is recommended for maximisation of profit. The optimum level of input use ensures 8.46 per cent increase in profits. Lower than optimum level of profit, yield and input use also indicate the presence of economic inefficiency in rice production. Therefore, attaining economic efficiency is crucial for sustainable rice production and livelihood of the rice growers. The relationship that exists among optimum levels of profit, yield and fertilizer use in paddy production is shown in figure 1.

In this figure, the state-wise estimation of the optimum level of profit, yield and input use was treated as an independent observation. The effect of an increase in fertilizer use on yield and then on profitability is clearly visible among states. Nevertheless, state-wise existing use of resources (variable inputs) is different than at the national level. There are states which use higher than optimal. Using the prevailing prices at state level, the demand of inputs at profit maximisation was estimated for each state and then compared with the existing use of inputs to find the overuse (above optimum) or underuse (below optimum) of particular inputs and the same has been given in table 4.

From a perusal of the table 4, it is worth noting that progressive states of Punjab, Haryana and Tamil Nadu overuse all the inputs. Although the average profit per hectare of these states is higher, but there is need to reduce the level of input use to make the paddy

Table 4. Categorisation of states as below optimum and above optimum use of selected variable inputs in paddy cultivation

	Below optimum	Above optimum
Seed	Andhra Pradesh, Bihar, Himachal Pradesh, Kerala, Odisha, Uttarakhand	Assam, Chattishgarh, Gujarat, Haryana, Karnataka, Punjab, Madhya Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh, West Bengal
Fertiliser	Andhra Pradesh, Assam, Bihar, Himachal Pradesh, Madhya Pradesh, Uttar Pradesh, Uttarakhand, West Bengal,	Chattishgarh, Gujarat, Odisha, Punjab, Karnataka, Kerala, Haryana, Tamil Nadu, Maharashtra
Manure	Andhra Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Uttar Pradesh	Chattishgarh, Maharashtra, Odisha, Tamil Nadu, Haryana, Punjab, Uttarakhand, West Bengal
Human Labour	Bihar, Chattishgarh, Himachal Pradesh, Kerala, Odisha, Uttarakhand	Andhra Pradesh, Assam, Karnataka, Madhya Pradesh Gujarat, Haryana, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal
Animal Labour	Chattishgarh, Himachal Pradesh, Kerala, Odisha	Bihar, Maharashtra, Tamil Nadu, Uttarakhand, West Bengal Andhra Pradesh, Assam, Gujarat, Haryana, Karnataka, Madhya Pradesh, Punjab, Uttar Pradesh

Source: Authors' compilation.

cultivation sustainable in long run from both environmental and economic points of view. Though paddy is labour intensive crop, we find over use human labour and animal labour in most states. It may be seen in the context of the existence of disguised unemployment in agriculture. Seed is also overused in most states which may be due to the fact that most of the farmers still use the broadcasting method of sowing which results in higher seed rate. The results clearly reveal that profit can be increased if the inputs are used optimally and the levels of optimal use of inputs differ across states. The results suggest a pathway that can be followed by each state in attaining the optimality. In a state, above optimum use of inputs are to be reduced while the below optimum use of inputs are to be increased. This will not only increase the profit of the farmer but also reduce degradation of soil and environment caused by the overuse of inputs like fertilizers.

4 Conclusions

The optimality in production while ensures maximum returns to the farmers, at the same time reduces the adverse effect on the environment due to overuse of inputs like fertilizer. Paddy is a crop in India which consumes the highest amount of major inputs besides being labour intensive. It is evident from the study that, on an average at the country level, most of the inputs used in paddy cultivation were below optimum level and their usage should be increased to attain profit maximising level of yield which was about 17% higher the existing average yield. However, state-wise existing use of resources (variable inputs) was different than that of their sub-optimal use at the national level. The states like Punjab, Haryana and Tamil Naidu used almost all the inputs more than optimum level while Andhra Pradesh and Bihar used all inputs except animal labour lower than the optimum level. The seed which accounted for 8.58 per cent of the cost of cultivation was overused in major rice-growing states namely Assam, West Bengal, and Chattisgarh while fertilizer was underused in all these states except Chattisgarh. The human and labour labour together accounted for about 80 per cent of the total cost, were found used above optimum in majority of the states. The results of the study clearly indicate a pathway that can be followed by each state in attaining the optimality. Within a state, above optimum use of inputs are to be reduced while the below optimum use of inputs are to be increased. The limitations of the study to include other inputs like irrigation, pesticides, machine labour etc., was due to non-availability of data on their prices and the quantity used. Future research might address these issues.

References

Chand, R. (1986). A note on the use of Cobb-Douglas profit function. American Journal of Agricultural Economics, 68(1), 162-164.

Chaudhary, M.K. & Harrington, L.W. (1993). Rice-wheat system in Haryana. Working paper, International Maize and Wheat Improvement Centre, Mexico.

GOI (Government of India).(2016 [a]). All India report on input survey 2011-12. Ministry of Agriculture and Farmers' Welfare, New Delhi.

GOI (Government of India). Various years [b]. Cost of cultivation/production & related data. Ministry of Agriculture and Farmers' Welfare, New Delhi.

Haque, T. (2006). Resource use efficiency in Indian Agriculture. Indian Journal of Agricultural Economics, 61(1), 65-76.

Kumar, S. V. (2005). Factor demand, output supply and technical efficiency of milk production in Tamilnadu. Ph.D. Thesis (unpublished), Division of Dairy Economics, Statistics and Management, Indian Council of Agricultural Research - National Dairy Research Institute, Karnal, India.

Mailena, L., Shamsudin, M. N., Mohammed, Z, & Radam, A. (2013). Optimality of input used, input demand and supply response of rice production: Experience in MADA Malaysia. Journal of Economics and Sustainable Development, 4(18), 71-76.

Prasad, R. (1999). A text book of rice agronomy. Jain Publishers. New Delhi.

Sidhu, S. S. & Baanante C. A. (1981). Estimating farm-level input demand and wheat supply in the Indian Punjab using a translog profit function. American Journal of Agricultural Economics, 63(2), 237-246.

Theil, H. (1971). Principles of Econometrics. John Wiley & Sons, New York.

Zellner, A. (1962). An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. Journal of American Statistical Association, 57(298), 348-375.