Asian Journal of Agricultural Extension, Economics & Sociology

39(11): 196-209, 2021; Article no.AJAEES.75146
ISSN: 2320-7027

Input Demand and Output Supply Elasticities of Coarse Cereals in India: A Translog Profit and Sure Approach

Radha R. Ashrit[1*]

[1]*Department of Biotechnology, Ministry of Science and Technology, New Delhi-110003, India.*

Author's contribution

This work was carried out in collaboration among all authors. Author RRA designed, conceptualized the study, data analysis, wrote the first draft of the manuscript; reviewed and approved the final manuscript.

Article Information

DOI: 10.9734/AJAEES/2021/v39i1130742
Editor(s):
(1) Wang Guangjun, Pearl River Fisheries Research Institute, China.
Reviewers:
(1) Rodrigo Monteiro da Silva, State University of Maringá, Brazil.
(2) Emmanuel Dodzi Kutor Havi, Methodist University College Ghana, Ghana.
(3) Nurdin, Universitas Muhammadiyah Jambi, Indonesia.
Complete Peer review History: https://www.sdiarticle4.com/review-history/75146

Original Research Article

Received 20 August 2021
Accepted 24 October 2021
Published 26 October 2021

ABSTRACT

Aims: The aim was to estimate the output supply and input demand elasticities of maize, jowar and bajra production, using the restricted normalised translog profit function, for the major producing states of India (Andhra Pradesh, Maharashtra and Rajasthan).
Study Design: A stratified multi-stage random sampling design was adopted for carrying out the sampling.
Place and Duration of Study: The study pertains to cross sectional plot level data for the period 2013-14 and 2017-18. The study is based on secondary data, collected from Directorate of Economics & Statistics, Ministry of Agriculture, Government of India.
Methodology: For the present studied crops (maize, jowar and bajra), those states were selected which covered maximum area, i.e, 85% of the total area under the cultivation. Socio-economic data of farmers such as age, sex, level of education, occupation, size of landholding were collected. The translog profit function approach was used as the econometric technique to estimate output supply, and input demand functions. Labour, fertiliser and seeds are taken as variable inputs. Statistical software STATA version 16 was used for the analysis.

**Corresponding author: E-mail: radhaaditijai@gmail.com;*

Results: The results suggest that the changes in market prices of inputs and output significantly affect the farmers' profits, crop produce supply and the use of resources in the cultivation of these crops. The supply elasticities of maize, jowar and bajra with respect to its own prices are positive and statistically significant indicating that increase in support prices can boost the supply of these nutri-grains and farmers profits. Labour demand for these crops in the country is elastic and significant to its own price.

Conclusion: During both the periods, 2013-14 (typical monsoon year) and 2017-18 (drought year), the elasticities derived are statistically robust as almost all of them carried compatible signs and in line with the theory. Promoting these crops can contribute to labour absorption.

Keywords: Normalised translog profit function; input demand; output supply; elasticity; crops.

1. INTRODUCTION

Coarse cereals or nutri-cereals are valued due to multi-purpose use as it has rich nutritional content with protein, vitamin, mineral, iron and folate [1]. It is used for feed and fodder use in India and other developing countries, providing food and nutritional security and maintaining livestock economy [2]. These crops are primarily grown in semi-arid tropical regions of Asia and Africa [1] under rain-fed farming systems, and they require little input cost and cultivation cost [3,4], which can increase the income of the farmers. Major coarse cereals cultivated in India are maize, jowar (sorghum), oats *(jai),* barley *(jau)*, pearl millet (bajra), finger millet (ragi), and small millets (kodo millet (arikalu), foxtail millet (kauni), little millet (Kutki), proso millet and barnyard millet (sanwa). More than 90% of coarse cereals are produced in 19 leading states, namely Rajasthan, Maharashtra, Karnataka, Uttar Pradesh, Madhya Pradesh, Gujarat, Andhra Pradesh, Haryana, Bihar and Tamil Nadu states [5]. Coarse cereals mainly spread in Rajasthan (area of 71.93 Lakh ha.), followed by Maharashtra (59.33 Lakh ha) and Andhra Pradesh (12.45 Lakh ha) [5]. Further, India stands in the 4th position in the production of coarse cereals globally [5], contributing 17% to the national food grain basket [5]. But regrettably, these coarse cereals have been pushed out of the food chain over time.

Despite their nutritional benefits and easy environmental conditions of cultivation, the yield of coarse cereals is limited in India due to their lower demand in the market [1], resulting in lower consumption of coarse grains in rural (5%) and urban areas (3%) [2]. Maize is an exception from other coarse cereals in yield, commercialisation, and demand [1], as it is included in the national policy schemes. One of the advantages is that maize cultivation has increased by 83% compared to all coarse cereals (bajra, jowar etc.), which declined by 40% [5].

Except for maize, national policies towards major coarse cereals have not been effective like they are for wheat or rice, and hence they do not generate revenue [6] and do not encourage small farmers to cultivate these coarse cereals. For example, coarse grains such as bajra, jowar have not been included in the public distribution system (PDS) [2], and are not part of the Green Revolution to meet the food security of the nation [1] whereas maize is included in the PDS. Further, the Commission of Agricultural Costs and Prices (CACP), Government of India, based on the cost of cultivation estimates announces the Minimum Support Price (MSP) for the farmers, which then the State government decide and adopt at their level under the 'The Agricultural Produce Market Committee (APMC) Act". Under this Act, state governments establish markets (mandis) for regulated trade of agricultural commodities through APMC's to prevent exploitation of farmers by traders. Although there are 23 crops (including coarse cereals), that are listed under the Price Support Scheme (PSS), but the MSP is adequate only for four crops; that is, wheat, paddy, cotton (modestly) and sugarcane [7].

The sensitivity of farmers to output and input prices, as formulated by policy instruments, determines the profitability and sustainability of farming in a country [8]. The rising input costs and demand-supply shifts in agricultural production and price fluctuations are harmful to small and marginal farmers (like bajra, jowar millet cultivators), which form a majority in India [5,9,10,11]. To the best of our knowledge, there are limited study from India estimate the coarse cereals' (maize, bajra, jowar) input demand and output supply elasticities during monsoon and drought periods. The main objective of the present study is to estimate input demand and output supply elasticities of three coarse cereals, namely maize, jowar and bajra, in the major producing states of India i.e., Andhra Pradesh, Maharashtra and Rajasthan, respectively, for the year 2013-14 and 2017-18. The study uses the Seemingly Unrelated Regression Equations (SURE) framework. This study uses the disaggregated, rich but untapped data collected from the Directorate of Economics & Statistics, Ministry of Agriculture, Government of India database. Further, the current study will help in providing a comprehensive picture of the coarse cereals for the last decade. It measures the impact of vital inputs such as the value of seeds, fertilisers, labour, and others on output price and supply changes. Moreover, the study estimates the own and cross-price demand elasticities for variable inputs. Furthermore, the study also focuses on the importance of output prices (MSP) for coarse cereals and how it can benefit the farmers and the country's nutritional security.

2. MINI-REVIEW

2.1 Restricted Normalized Translog Profit Function-A Flexible Econometric Method

In the literature, various econometric methods have been used to estimate the price elasticity of input demand and output supply for major crops [12,13]. It has been found that the Cobb Douglas production function (CD) approach, based on the assumptions of a unitary elasticity of substitution (with constant returns to scale subject to the separability of inputs that are highly restrictive in nature), yields invalid elasticities that may not be able to explain the real relationship between inputs and output [14]. Moreover, elasticities are also estimated through production functions with variable elasticity of substitution (VES), constant elasticity of substitution (CES), and the nested CES production functions. Although these are considered better than the CD form, but are based on restrictive assumptions. Some authors have used the translog cost function approach to develop input demand and output supply elasticities [15,16,17]. Studies have also used the profit function to estimate factor demand and output supply parameters [12,13,18]. Among the various functional forms, a flexible structure [19,20,21] such as translog, normalised quadratic and generalised Leontief is usually preferred. The production function approach is appropriate to estimate elasticities if the inputs used in the production system are exogenous. However, in reality this may not be true. Although variable inputs in the farm sector can be weakly termed to be exogenous, the fixed variables such as land, irrigation facilities, etc. may be endogenous. In order to overcome the problem of endogeneity of the important input variables, researchers have preferred the cost function approach over production function. However, the cost function approach has its own limitations. The cost of variable inputs is exogenous if market conditions are perfectly competitive. In real life, this condition may not hold true. In the cost function approach, variables of quality cannot be included, though it has implications for the cost structure. A more accommodative approach, i.e., the profit function approach is preferred to estimate input demand and output supply elasticities [22]. Lopez [21], stressed on the merits of using a profit function as compared to a cost or revenue function, because it avoids inconsistencies due to simultaneous equation problems. Therefore, profit function is used to derive input demand and supply response functions and apply Hotelling’s Lemma to derive elasticities [23].

2.2 Factors Affecting Profitability in Maize, Jowar and Bajra Production

Although literature from India on elasticities on input demand and output supply for production of two main crops i.e, wheat and rice, are widely available [12,24,25,26,27,28] but there are very limited literature on maize, sorghum (Jowar) and pearl millet (bajra) using various econometric methods such as Cobb-Douglas cost function and others [29,30,31,32,33]. Various price and non-price factors were reported, affecting the profitability in Maize, Jowar and Bajra Production using exclusively translog profit function. Few studies that used translog profit function for Maize, Jowar and Bajra are discussed below. A study conducted in Nigeria reported that profit efficiency in maize production can be improved with improvement in the level of education of farmers [34]. Further the authors stated that low productivity in maize production has led to increase in the price of maize [34]. No use of fertilizers, no use of improved seeds and increased price of the inputs were few factors for low productivity of maize [34]. A study in Ghana, Africa, reported that profitability of maize production were adversely affected if prices of relevant inputs such as pesticides, fertiliser, herbicides, labour and seeds increased. Poor access to resources for farmers in maize production results in increased maize price. Additionally, in maize production, profit efficiency was influenced by education [35]. Whereas in Bangladesh, the profitability of maize production depended on the land availability/holding and smooth functioning of the labor market [36]. In Jowar (Sorghum) production, increase in wage rates reduces the Jowar supply as reported by Bapna & co-authors (1984).

3. METHODOLOGY

3.1 Data Sources

The database on "Comprehensive Scheme for Studying the Cost of Cultivation of Principal Crops in India" was used for the current analysis for the year 2013-2014 and 2017-2018 [37,38,39]. The latest plot level data on maize, jowar and bajra crops is available for the year 2017-18 from Directorate of Economics & Statistics, Ministry of Agriculture, Government of India, no plot level data available after year 2017-18 for the studied crops.

3.2 Study Design

A stratified multi-stage random sampling design was adopted for carrying out the sampling. A statistically representable sample from 19 Indian states, on selected crops was considered for the survey. Sampling design details are mentioned at the Ministry of Agriculture, Government of India [37].

3.3 Data Collection

Data on inputs and output in physical and monetary terms for estimation of the cost of cultivation per hectare and production per quintal of principal crops was available in the database. For the present studied crops, those states were selected which covered maximum area, i.e, 85% of the total area under the cultivation. The data of the socio-economic details of the farmers such as age, sex, level of education, occupation, size of landholding etc, information on the net sown area, irrigation type, soil type, seasonality of crops, the quantity of the produced crops and inputs (labour, fertilisers, seed, machinery utilised etc) were also collected [37,38,39].

3.4 Econometric Analysis

To estimate various input demand and output supply elasticities in the current study, a generalisation of the normalised restricted translog profit function mentioned by Sidhu and Baanante [12], was applied. Translog form of the profit function is a flexible functional form, not imposing "a priori" restrictions on the production function associated with it. This function is as follows:

$$\boldsymbol{ln\,\pi^*} = \boldsymbol{\alpha_0} + \sum_{i=1}^{n} \boldsymbol{\alpha_i \ln P_i^*} + \frac{1}{2}\sum_{i=1}^{n}\sum_{h=1}^{n} \boldsymbol{\gamma_{ih}\, lnP_i^* \ln P_h^*} + \sum_{i=1}^{n}\sum_{k=1}^{n} \boldsymbol{\delta_{ik}\, lnP_i^*\, lnZ_k} + \sum_{k=1}^{n} \boldsymbol{\beta_k \ln Z_k} + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m} \boldsymbol{\phi_{kj}\; lnZ_k\, lnZ_j} + \boldsymbol{\varepsilon} \qquad \text{(i)}$$

where

$\gamma_{ih} = \gamma_{hi}$ for all h, i, and it is the first-degree homogenous function of prices of all variable inputs and output.
π^* = restricted profit: i.e., total costs of variable inputs are deducted from the total value of output and normalised by P_y the price of output;
P_i * = price of the variable input X_i normalised by P_y;
Z_k = kth fixed input; i = h = 1, 2, 3, ... , n + k = j = 1, 2, 3, ... , m;
ε = error term, which follows normal distribution with constant variance.
ln = natural logarithm and
α_0, α_i, γ_{ih} , δ_{ik} , β_k, and Φ_{kj} are the parameters to be estimated.

Differentiating equation (i) with respect to normalised factor price of that input P_i^* and the price of output generates a system of variable input/profit ratio and an output/profit ratio.

From the translog profit function (i), the share equation can be written as

$$S_i = -\frac{P_i^* X_i}{\pi*} = \frac{\partial ln\pi*}{\partial lnP_i^*} \qquad \text{(ii)}$$

$$= \alpha_i + \sum_{h=1}^{n} \gamma_{ih}\, lnP_h^* + \sum_{k=1}^{m} \delta_{ik}\, lnZ_k$$

Where

$X_i =$ quantity of input i used in production,
$S_i = -\frac{P_i^* X_i}{\pi*}$ = denotes the share of expenditure of i[th] variable input in the normalised restricted profit. The ratio of the value of output to normalised restricted profit can be written as $S_v = \frac{V}{\pi^*}$. Differentiating equation (i) with respect to $lnP_i^*\ and\ lnP_y$ generates the variable input profit ratio functions and an output/ profit ratio function.

Estimations for the variable input demand and output supply elasticities can be obtained from the model [12].

The own price elasticities for the variable input demand is

$$\eta_{ii} = -S_i^* - 1 - \frac{\gamma_{ii}}{S_i^*} \quad \text{(iii)}$$

The cross-price elasticities of input demand is

$$\eta_{ih} = -S_h^* - \frac{\gamma_{ih}}{S_i^*} \quad \text{(iv)}$$

The cross price elasticity of demand for input i with respect to output price P_y (η_{iy}) is

$$\eta_{iy} = \sum_{i=1}^{n} S_i^* + 1 + \sum_{h=1}^{n} \frac{\gamma_{ih}}{s_i^*} \quad \text{(v)}$$

Output supply elasticities with respect to output price and prices of input variables evaluated at given levels of output variables can also be written as linear functions of the restricted profit functions parameters. The elasticity of output supply (ϵ_{vi}) with respect to the ith variable input price is

$$\epsilon_{vi} = -S_i^* - \sum_{h=1}^{n} \frac{\gamma_{hi}}{(1+\sum_{h=1}^{n} S_h^*)} \quad \text{(vi)}$$

The own price elasticity of supply(ϵ_{vv}) is

$$\epsilon_{vv} = \sum_{i=1}^{n} S_i^* + \sum_{i=1}^{n} \sum_{h=1}^{n} \frac{\gamma_{ih}}{(1+\sum_{h=1}^{n} S_h^*)} \quad \text{(vii)}$$

3.5 Empirical Specification

The normalised restricted translog profit function is specified as:

$$\ln \pi^* = \alpha_0 + \alpha_L \ln P_L^* + \alpha_F \ln P_F^* + \alpha_S \ln P_S^* + \frac{1}{2}\gamma_{LL} \ln P_L^* \ln P_L^* + \frac{1}{2}\gamma_{FF} \ln P_F^* \ln P_F^* + \frac{1}{2}\gamma_{SS} \ln P_S^* \ln P_S^* + \gamma_{LF} \ln P_L^* \ln P_F^* + \gamma_{LS} \ln P_L^* \ln P_S^* + \gamma_{FS} \ln P_F^* \ln P_S^* + \sum_{k=1}^{3} \delta_{LK} \ln P_L^* \ln Z_k + \sum_{k=1}^{3} \delta_{FK} \ln P_F^* \ln Z_k + \sum_{k=1}^{3} \delta_{SK} \ln P_S^* \ln Z_k + \sum_{k=1}^{3} \beta_K \ln Z_k + \frac{1}{2}\sum_{K=1}^{3} \varphi_{KK} \ln Z_k \ln Z_k + \varphi_{12} \ln Z_1 \ln Z_2 + \varphi_{13} \ln Z_1 \ln Z_3 + \varphi_{23} \ln Z_2 \ln Z_3 + \Theta_1 \text{ soil\_quality} + \Theta_2 \text{ type of irrigation} \quad \text{(viii)}$$

where

restricted Profit (π^*) (for each crop) used in the analysis is estimated as the value of output deducted from variable input costs normalised by output price. This restricted profit is defined as a function of variable input prices normalised by the output price, fixed inputs such as crop area, value of machinery normalised by output price, educational level of the farmer and two dummy variables, i.e., type of irrigation and quality of soil.

In our study, there are many farmers with negative returns from farming activities. This situation is more prominent for farmers growing *jowar* and *bajra*. In the empirical specification, the logarithmic values of restricted profits are not defined. In order to accommodate omitted information, the restricted profit has been rescaled as $\pi + |min\pi| + 1$ (π represents restricted profit) to overcome the loss of information due to the negative values of restricted profit figures [40].

P_L^* = price of labour input (variable in nature), defined as the wage rate per hour normalised by the value of output. The wage rate is obtained by dividing total expenditure on labour*[1] per farm by the quantity of labour including family, hired and attached labour.
P_F^* = defined as the price per kg of fertiliser normalised by the price of output and is obtained by dividing total fertiliser costs per farm by the quantity of fertiliser used.
P_S^* = defined as the per kg price of seeds normalised by the price of output (obtained by dividing total seed costs per farm by quantity of seeds used).
The three fixed inputs Z_k, defined in the specification of the profit function are:
Z_1 = land input measured as hectares of crop grown per farm,
Z_2 = value of capital equipment and the machinery used for crop production per farm measured in rupees and
Z_3 = measured as the average years of schooling of family member above 13 years of age in the farm family.

Besides, two dummy variables such as soil quality (clayey and loamy soil are considered to be more fertile and takes the value 1; other soil take the value zero) and type of irrigation used (all types of irrigation such as well, canals, etc., take the value 1; otherwise, zero).

The parameters $\alpha_0, \alpha, \gamma, \delta, \beta, \varphi$ *and* θ are to be estimated and subscripts L, F and S stand for labour, fertiliser and seeds respectively.

*[1] *Total expenditure on labour includes wages of family labour (imputed), attached labour and hired labour.*

Following equation (ii), S_i functions for labour, fertilisers and seeds are arrived at by differentiating the normalised restricted translog profit function (viii) as shown below

$$-\frac{P_L^{*}.X_L}{\pi^{*}} = \alpha_L + \gamma_{LL} lnP_L^{*} + \gamma_{LF} lnP_F^{*} + \gamma_{LS} lnP_S^{*} + \sum_{k=1}^{3} \delta_{LK} lnZ_k, \quad \text{(ix)}$$

$$-\frac{P_F^{*}.X_F}{\pi^{*}} = \alpha_F + \gamma_{FF} lnP_F^{*} + \gamma_{FL} lnP_L^{*} + \gamma_{FS} lnP_S^{*} + \sum_{k=1}^{n} \delta_{FK} lnZ_K, \quad \text{(x)}$$

$$-\frac{P_S^{*}.X_S}{\pi^{*}} = \alpha_S + \gamma_{SS} lnP_S^{*} + \gamma_{SL} lnP_L^{*} + \gamma_{SF} lnP_F^{*} + \sum_{k=1}^{n} \delta_{SK} lnZ_K, \quad \text{(xi)}$$

where X_L, X_F and X_S are quantities of labour, fertilisers and seeds respectively. The model, consisting of the normalised restricted translog profit function (viii) and S_i functions (ix), (x) and (xi). All the analysis was carried out using the Statistical software STATA version 16.

4. RESULTS AND DISCUSSION

The elasticities were computed for output supply and input demand regarding own price, cross-price, input price and output price with respect to certain factors such as labour, fertiliser and seed used in maize, bajra and jowar cultivation in Andhra Pradesh, Rajasthan and Maharashtra states of India. Further, the difference in trend or magnitude of elasticities during 2013-2014 and 2017-2018 in cultivation of maize, bajra and jowar was also estimated. The econometric technique used in our study was the translog profit function approach that applies Hotelling's Lemma to derive elasticities, as also preferred by others [19,21,41].

It may be noted that researchers often met with estimation problems such as heteroscedasticity, while analyzing agricultural profits explained by major inputs such as labour, fertiliser, seeds and others. This may be due to the existence of larger variations in income by farmers who may have incurred higher amount of expenditure on the inputs mentioned above than those farmers who have invested less on them. Moreover, we use the logarithmic transformation in the analysis which often minimizes heteroscedasticity related problems. It is assumed that as the analysis is being done for the cross-sectional data the problem arising out of serial correlation may not be a serious issue. It has been assumed that error terms of the profit function used in the study have constant variance with mean 0. Therefore, it is considered that the profit function employed in the analysis follows normal distribution for all the crops. Similar studies have also employed the same model specifications [12,42].

Descriptive statistics of factors in profit function analyses of the studied major coarse cereals are shown in Table 1. During 2013-2014 and in 2017-2018, the number of farmers with negative profit was maximum for bajra, followed by jowar and maize crops. This indicated that maize had emerged as a profitable crop based on the average per farm net returns compared to jowar and bajra because reduced cost of fertiliser and seeds helped to increase profit in maize cultivation. During the year 2013-14, average restricted profit was found highest for maize followed by jowar and bajra; while in the year 2017-18, the average restricted profit was found highest for bajra followed by maize and jowar (Table 1). The average input costs for labour, fertiliser and seeds were maximum for maize during 2013-2014 and 2017-2018. The average crop area (in hectares) under cultivation was highest for maize followed by bajra and jowar during 2013-2014 and 2017-2018. The cultivation area for all three crops did not exceed 2 hectares, indicating the engagement of small farmers in the cultivation of these crops. No difference was found in the education level of farmers engaged in the cultivation of maize, bajra and jowar from 2013-2014 to 2017-2018 (in terms of number of years) (Table 1).

Further, the estimates of the translog profit function and the demand equation for labour, fertiliser and seeds for maize, bajra and jowar crops during the year 2013-14 and 2017-18 were presented in Table 2a and Table 2b.

For maize, the coefficient of the squared term of both fertiliser and seeds was found negative and significant and with no change from the year 2013-14 to 2017-18, indicating that reduced cost of fertiliser and seeds helped increase profit in maize cultivation. Similarly, the coefficient of interaction term of fertiliser and seed was also found negative and significant. No change was found in the coefficient of interaction term of fertiliser and seed from 2013-14 to 2017-18 (Table 2a and Table 2b), suggesting that persistently reduced input cost of fertiliser and seed is necessary for profitable maize cultivation. Further, the coefficient of the squared term of land measure and squared term of machinery were found positive and significant, indicating that a decrease in land measure and decrease in value of machinery will decrease profit in maize cultivation (Table 2a and Table 2b).

Table 1. Descriptive statistics of factors affecting profit function analysis of three major grains cultivated in the year 2013-2014 and 2017-2018

		Year: 2013-14			Year: 2017-18		
		Maize Andhra Pradesh	Bajra Rajasthan	Jowar Maharashtra	Maize Andhra Pradesh	Bajra Rajasthan	Jowar Maharashtra
Number of observations		194	378	227	114	314	137
Number of observations with negative profit		2 (1.03%)	189 (50%)	63 (27.7%)	9 (7.90%)	275(87.58%)	75 (54.75%)
Restricted Profit per ha (in Rs)	Mean	4573.63	145.33	391.19	6491.47	9572.01	2382.8
	Min	-1281	-3351.8	-891.07	2.5	0.47	3
	Max	20840.7	4299.11	13944.2	18670.4	51734.9	9571.33
Mean Output price per ha (in Rs)		12.24	11.37	16.64	16.09	17.6	50.05
Average cost per ha (in Rs)	Labour	18559.8	10193.2	7624.73	22331.7	19201.3	18247.2
	Fertiliser	7488.73	480.09	1621.95	8729.76	961	2832.78
	Seeds	4647.99	762.75	429.41	5280.01	1115.25	567.47
Avg crop area (ha)		1.15	0.94	0.71	1.41	1.09	0.59
Avg education (years)		6.12	4.96	6.67	6.28	4.5	6.1

Source: Author's calculations

For bajra, no association was found between the cost of input variables, i.e., labour, fertiliser, seed, land measure and value of machinery with a profit of bajra cultivation during the year 2013-14 and year 2017-18 (Table 2a and Table 2b).

Although, for jowar, there was no association found between the cost of input variables, i.e., labour, fertiliser, seed, land measure and value of machinery with a profit of jowar cultivation during the year 2013-14, a noticeable change was observed during the year 2017-18. During 2017-18, the coefficient of input cost of labour was found positive and significant, indicating that profit in jowar cultivation is dependent on the change in the wage rate. Further, the coefficient of interaction term of labour and fertiliser and the interaction term of labour and seed were found negative and significant, indicating that reduced fertiliser and seed cost will increase profit in jowar cultivation (Table 2b).

The input demand and output elasticities were estimated for maize, bajra and jowar during 2013-14 and 2017-18, as shown in Table 3a and Table 3b.

4.1 Output Supply Vis-à-vis Output Prices

4.1.1 Maize

Response of output supply to the price of maize was estimated to be 0.85 and 2.34, which are positive and statistically significant for the years 2013-14 and 2017-18. The output supply has nearly doubled for the unit increase of the price, i.e., 0.85 in 2013-14 to 2.34 in 2017-2018 (Table 3a and Table 3b).

4.1.2 Bajra

During 2013-14, the elasticity of output supply to its price was estimated at 2.65, and statistically significant. However, there was an approximately three fold increase in bajra output, i.e., 7.75 from 2013-14 to 2017-2018 for one unit of increase in output prices (Table 3a and Table 3b).

4.1.3 Jowar

During the year 2013-14, the response of output supply to the price of jowar was estimated at 2.98, which is statistically significant. However, it increased to 4.70 from 2013-14 to 2017-2018 (Table 3a and Table 3b). The increase of 1%

in the price of jowar will increase output by 4.70%.

Results suggest that compared to the year 2013-14, the output of maize, bajra, and jowar are more than double in 2017-18 when there was a 1% increase in the price of these crops. Furthermore, higher crop price support will encourage farmers to produce more.

4.2 Output Supply Vis-à-vis Input Prices

The results showed that an increase in wage rate mainly decreases the output supply of all three crops, i.e., maize, bajra and jowar (Table 3a and Table 3b). The decreasing trend on the output supply of maize, bajra and jowar crops with respect to a 1% increase in wage rate was found double for maize and jowar and triple for bajra from 2013-14 to 2017-2018.

Table 2a. Parameter estimates with translog profit approach for maize, bajra and jowar in 2013-14

	Maize (Andhra Pradesh)		**Bajra (Rajasthan)**		**Jowar (Maharashtra)**	
ln π*	Coefficient	t-Stat	Coefficient	t-Stat	Coefficient	t-Stat
ln P_L	-0.54	-0.85	-1.21	-0.41	0.86	0.70
ln P_F	0.17	0.94	-0.49	-1.61	0.45	1.05
ln P_S	0.12	1.11	-0.95	-1.57	0.03	0.15
ln P_L * ln P_L	0.20	0.70	-0.74	-0.57	-0.13	-0.17
ln P_F * ln P_F	-0.19^{***}	-6.09	0.08	1.15	0.08	0.59
ln P_S * ln P_S	-0.07^{***}	-3.93	0.08	0.87	-0.04	-1.05
ln P_L * ln P_F	0.03	0.42	-0.11	-0.90	0.16	0.63
ln P_L * ln P_S	0.06	1.17	0.50^{*}	1.79	-0.02	-0.25
ln P_F * ln P_S	-0.03^{*}	-1.84	0.08^{**}	2.36	0.03	0.52
ln P_L * ln Z_1	-0.02	-0.18	-0.16	-0.38	-0.05	-0.15
ln P_F * ln Z_1	0.00	0.01	0.06	1.07	-0.11	-0.90
ln P_S * ln Z_1	0.00	-0.10	-0.04	-0.49	-0.07	-1.27
ln P_L * ln Z_2	0.05	0.61	0.09	0.22	-0.09	-0.38
ln P_F * ln Z_2	0.01	0.29	0.00	-0.07	-0.02	-0.21
ln P_S * ln Z_2	0.00	0.23	0.03	0.46	0.04	1.22
ln P_L * ln Z_3	0.01	0.37	-0.02	-0.38	-0.04	-0.82
ln P_F * ln Z_3	0.00	0.13	0.00	0.43	0.01	0.41
ln P_S * ln Z_3	0.00	0.42	-0.01	-0.70	0.00	-0.72
ln Z_1	-0.70	-1.24	0.52	0.55	-0.10	-0.12
ln Z_1 * ln Z_1	0.47^{***}	2.93	0.13	0.53	0.05	0.17
ln Z_2	-0.60	-1.34	0.01	0.02	-0.48	-0.72
ln Z_2 * ln Z_2	0.14^{***}	2.87	0.03	0.23	0.07	0.50
ln Z_3	0.07	0.97	0.02	0.17	-0.01	-0.06
ln Z_3 * ln Z_3	0.00	-0.44	0.01	0.96	0.00	-0.25
ln Z_1 * ln Z_2	-0.10	-1.52	-0.10	-0.64	0.01	0.05
ln Z_1 * ln Z_3	0.00	0.23	-0.01	-0.33	0.01	0.29
ln Z_2 * ln Z_3	-0.01	-0.88	0.00	0.10	0.00	0.14
Irrigation type	-0.13^{*}	-1.71	-0.25	-0.72	0.00	0.02
Soil quality	0.00	0.01	0.04	0.24	-0.04	-0.26
negative _profit	-0.62^{*}	-1.65	-0.15	-1.03	-0.34^{**}	-2.15
Constant	10.12^{***}	4.77	9.49^{**}	2.33	8.91^{***}	3.79

Note: ln π: value of output deducted from variable input costs normalised by the output price*
ln P_L : the wage rate of labour per hour normalised by the value of output.
ln P_F : total fertiliser costs per farm by quantity of fertiliser used normalised by the value of output
ln P_S: total seed costs per farm by quantity of seeds used normalised by the value of output
*ln P_L * ln P_L: square term of ln P_L; ln P_F * ln P_F: square term of ln P_F; ln P_S * ln P_S: square term of ln PS*
*ln P_L * ln P_F: cross product of ln P_L and ln P_F . Similarly, other cross products are also defined*
ln Z_1: land measure in hectares; ln Z_2: value of machinery per farm; ln Z_3: age of the farmer ; Soil quality: clayey and loamy soil take the value 1; otherwise, zero
Irrigation type: all types of irrigation take the value 1, otherwise zero
*P-value <0.01;** P-value <0.05; * P-value <0.1;*
Source: Author's calculations

Table 2b. Parameter estimates with translog profit approach for maize, bajra and jowar in 2017-18

	Maize (Andhra Pradesh)		Bajra (Rajasthan)		Jowar (Maharashtra)	
ln π*	**Coefficient**	**t-Stat**	**Coefficient**	**t-Stat**	**Coefficient**	**t-Stat**
ln P_L	-0.54	-0.85	-0.50	-0.06	7.19**	2.42
ln P_F	0.17	0.94	0.53	0.39	-0.96	-1.34
ln P_S	0.12	1.11	-0.53	-0.66	0.10	0.35
ln P_L * ln P_L	0.20	0.7	0.92	0.26	-0.54	-0.28
ln P_F * ln P_F	-0.19***	-6.09	0.19	0.61	-0.13	-0.5
ln P_S * ln P_S	-0.06***	-3.93	0.10	1.26	-0.06	-1.56
ln P_L * ln P_F	0.03	0.42	-0.67	-1.15	-1.02**	-2.08
ln P_L * ln P_S	0.05	1.17	0.05	0.14	-0.31*	-1.67
ln P_F * ln P_S	-0.03**	-1.84	0.03	0.32	0.01	0.16
ln P_L * ln Z_1	-0.02	-0.18	-0.21	-0.22	-1.21**	-2.07
ln P_F * ln Z_1	0.00	0.01	0.05	0.24	0.30	1.55
ln P_S * ln Z_1	-0.00	-0.1	-0.00	-0.05	0.07	0.99
ln P_L * ln Z_2	0.05	0.61	0.07	0.08	-0.42	-1.07
ln P_F * ln Z_2	0.00	0.29	-0.03	-0.23	0.00	0.08
ln P_S * ln Z_2	0.00	0.23	0.02	0.26	-0.01	-0.25
ln P_L * ln Z_3	0.00	0.37	-0.09	-0.87	0.24***	2.81
ln P_F * ln Z_3	0.00	0.13	-0.00	-0.23	-0.03	-1.19
ln P_S * ln Z_3	0.00	0.42	-0.00	-0.63	-0.00	-0.78
ln Z_1	-0.69	-1.24	2.71	1.07	-2.20**	-2.26
ln Z_1 * ln Z_1	0.47***	2.93	-0.33	-0.56	0.05	0.11
ln Z_2	-0.59	-1.34	0.16	0.07	0.42	0.72
ln Z_2 * ln Z_2	0.14***	2.87	0.07	0.35	-0.20**	-2.15
ln Z_3	0.06	0.97	0.00	0.01	-0.01	-0.1
ln Z_3 * ln Z_3	-0.00	-0.44	0.00	0.11	-0.00	-0.48
ln Z_1 * ln Z_2	-0.100	-1.52	-0.17	-0.50	0.35	1.49
ln Z_1 * ln Z_3	0.00	0.23	0.07	1.46	-0.00	-0.09
ln Z_2 * ln Z_3	-0.00	-0.88	-0.01	-0.51	-0.00	-0.34
Irrigation type	-0.12*	-1.71	-0.07	-0.17	0.07	0.3
Soil quality	0.00	0.01	-0.23	-0.62	-0.31	-0.82
negative _profit	-0.62**	-1.65	-0.21	-0.4	-0.70***	-3.40
Constant	10.12***	4.77	4.02	0.31	8.26**	2.46

Note: ln π: value of output deducted from variable input costs normalised by the output price*
ln P_L : the wage rate of labour per hour normalised by the value of output.
ln P_F : total fertiliser costs per farm by quantity of fertiliser used normalised by the value of output
ln P_S: total seed costs per farm by quantity of seeds used normalised by the value of output
*ln P_L * ln P_L: square term of ln P_L; ln P_F * ln P_F: square term of ln P_F; ln P_S * ln P_S: square term of ln PS*
*ln P_L * ln P_F: cross product of ln P_L and ln P_F . Similarly, other cross products are also defined*
ln Z_1: land measure in hectares; ln Z_2: value of machinery per farm; ln Z_3: age of the farmer ; Soil quality: clayey and loamy soil take the value 1; otherwise, zero
Irrigation type: all types of irrigation take the value 1, otherwise zero
*P-value <0.01;** P-value <0.05; * P-value <0.1;*
Source: Author's calculations

Although an increase in inputs such as fertiliser and seed prices marginally decrease the output supply of maize, bajra and jowar crops; however, fertiliser and seed prices had less effect on the output supply of these crops than wage rate input. The results were similar from 2013-14 to 2017-2018 (Table 3a and Table 3b).

4.3 Input Demand Vis-à-vis Output Prices

The results showed that with an increase in output prices of maize, bajra and jowar crops; the demand for labour, fertilisers and seeds inputs increased significantly during the year 2013-14 and also during the year 2017-2018 (except for fertiliser and seeds inputs in case of jowar during

2017-18). Further, it showed that demand for labour was the most critical input for maize; fertiliser for bajra and fertiliser and labour for jowar from 2013-14 to 2017-2018 (Table 3a and Table 3b).

4.4 Own-Price Elasticities of Inputs

There was variation in the association of demand of inputs with input prices of maize, bajra, and jowar from 2013-14 to 2017-2018. In the case of maize, during the year 2013-14, the demand for labour and seed inputs was found to be significantly declined with an increase in input price, while during the year 2017-2018, labour and fertiliser inputs demand decreased with an increase in input price. Similarly, in the case of bajra, the demand for labour significantly declined with an increase in input price during the year 2013-14 and 2017-2018. Whereas, in the case of jowar, the demand of all the parameters, i.e., labour, fertiliser, and seeds, were found to be significantly declined with an increase in input price during the year 2013-14, but only the demand for labour significantly declined during 2017-2018 (Table 3a and Table 3b).

All the elasticities showed the expected signs during both 2013-2014 and 2017-2018 w.r.t maize, bajra and jowar cultivation, which was consistent with the theory and other studies [8,12,42,43,44]. Firstly, all input elasticities with respect to own price showed a negative sign as expected and were significant (except for jowar w.r.t seeds in 2017-18, though not significant). Others reported similar findings for wheat, paddy/rice, cotton and mixed cropping cultivation [8,12,43,44]. Secondly, Cross price elasticities with inputs such as labour, fertiliser, and seed are negative and significant, implying complementarity of the inputs (except for jowar w.r.t labour during 2017-18, though not significant). This suggests that the increase in labour wages will decline demand for fertiliser and vice versa in all three coarse cereals. A similar trend was also found by Rahman and others [36] in the case of maize cultivation [36]. Although for bajra and jowar, there is no study for comparison. Thirdly, the demand for inputs such as labour, fertiliser and seeds with output price was positive and significant (except for jowar w.r.t fertiliser and seeds labour during 2017-18, though not significant). This implies that an increase in the output price of all three cereal crops had increased the demand for inputs. In the present study, labour was the main input for maize production, fertiliser for bajra production, and labour and fertiliser for jowar production. A similar trend was reported by Rahman and others [36] in the case of maize cultivation, where they reported that with the increase in output price of maize, the demand for fertiliser and labour would increase, with labour being the primary variable input maize production [36]. Fourthly, elasticities of output supply with input price showed significant and negative signs (except for jowar w.r.t fertiliser and seeds labour during 2017-18, though not significant).

On the other hand, elasticities of output supply with output price showed significant and positive signs for all three coarse cereals. This implies that farmers are price sensitive; hence, the increase in maize, bajra and jowar price is necessary for higher production of these crops. It was also found that a 1% increase in maize price increased the output supply by 2.34% during

Table 3a. Input demand and output supply elasticities for maize, bajra and jowar in 2013-14

	Maize			Bajra			Jowar		
	Labour	**Fertiliser**	**Seed**	**Labour**	**Fertiliser**	**Seed**	**Labour**	**Fertiliser**	**Seed**
Own price elasticities w.r.t inputs									
	-1.91**	-0.14	**-0.48****	**-3.48****	-3.93	-2.22	**-3.57****	**-1.65****	**-0.83****
Cross price elasticities w.r.t inputs									
Labour	-	-0.25	**-0.22****	-	-0.1	-0.25	**-**	**-0.23****	**-0.13****
Fertiliser	-0.7	-	0.06	-7.04	-	-1.6	**-3.57****	-	-0.29
Seed	**-1.04****	0.11	-	-5.13	-0.46	-	**-2.44****	-0.36	-
Input demand vis-à-vis output prices									
	2.38**	0.78	**1.42****	**3.82****	**12.57****	**7.81****	**3.93****	**5.51****	**3.62****
Output supply vis-à-vis input prices									
	-0.68**	-0.08	**-0.08****	**-2.32****	**-0.11****	**-0.23****	**-2.62****	**-0.23****	**-0.13****
Output supply vis-à-vis output prices									
	0.85**			**2.65****			**2.98****		

*** P -value <0.01& 0.05; Source: Author's calculations*

Table 3b. Input demand and output supply elasticities for maize, bajra and jowar in 2017-18

	Maize			Bajra			Jowar		
	Labour	**Fertiliser**	**Seed**	**Labour**	**Fertiliser**	**Seed**	**Labour**	**Fertiliser**	**Seed**
Own price elasticities w.r.t inputs									
	-2.80**	**-0.87****	-0.98	**-7.83****	-2.45	-1.65	**-5.92****	-0.31	0.21
Cross price elasticities w.r.t inputs									
Labour	-	**-0.63****	**-0.36****	-	-0.35	**-0.52****	**-**	0.04	0.01
Fertiliser	**-1.71****	-	-0.04	-8.46	-	-0.90	1.41	-	-0.13
Seed	**-2.45****	-0.10	-	**-7.02****	-0.51	-	1.35	-0.42	-
Input demand vis-à-vis output prices									
	3.80**	**2.63****	**3.53****	**8.71****	**11.81****	**9.18****	**5.36****	-0.97	-1.14
Output supply vis-à-vis input prices									
	-1.68**	**-0.43****	**-0.23****	**-6.82****	**-0.40****	**-0.53****	**-4.72****	0.02	0.009
Output supply vis-à-vis output prices									
	2.34**			**7.75****			**4.70****		

*** P-value <0.01& 0.05; Source: Author's calculations*

2017-18, which is a threefold increase in magnitude from the year 2013-14. A similar trend was reported by Rahman and others [36] in maize cultivation, but the output supply response is much higher for maize in the current study [36]. Although bajra and jowar also responded similarly in output supply response to maize cultivation, there are no studies to compare with these crops. Hence, the current study results confirm that price factors like labour (wage rate), fertiliser and seeds are essential for the cultivation of maize, bajra and jowar in the selected states of India (A.P, Rajasthan and Maharashtra). Contrastingly, a study done by Sadasivam [42] found that fixed factors like rainfall and the cost of irrigation have a more significant impact than the price factors using the translog profit function, but the study was conducted on gram cultivation[42]. While the trend of elasticities for output supply and input demand for own price, cross-price, input price, output price found in the current study were concordant with the findings of Sindhu and Bannante (1981) research but the study was on wheat [12]; therefore the results cannot be compared with coarse cereals. The present findings cannot be generalised for other crops.

5. CONCLUSION

The study empirically explores the effects of input and output prices on demand for inputs and supply of output for the coarse cereals, namely maize, bajra and jowar, in three states of India, Andhra Pradesh, Rajasthan and Maharashtra. During both the periods, 2013-14 (typical monsoon year) and 2017-18 (drought year), the results showed that the elasticities derived are statistically robust as almost all of them carried compatible signs and sizes in line with the theory. The present study showed solid evidence for the policymakers to raise the MSP and the procurement of these coarse cereals, preferably at the state level. Although the trend of elasticities during 2013-2014 and 2017-2018 for three cereals was similar, an increase was observed in magnitude during 2017-2018. Hence, it was suggested that policymakers must enhance the MSP for supporting the production of these coarse cereals. In this manner, the support to farmers by reducing their input cost and assuring affordable MSP will lead to enhanced output prices.

Notably, labour and fertiliser elasticities to output prices are generally more than the unity and statistically significant. Low substitutability among variable inputs was observed, indicating that the mutual application of all three inputs is necessary for crop cultivation. Further, crop-specific inputs may be given more preference to assure higher production and profitability. It is also recommended that the labour absorption be enhanced as the demand for labour input was essential for the coarse cereals. The system can absorb the existing educated rural youth with minimum investments to increase the yield of the coarse cereals.

Furthermore, the provision of other needed facilities such as capital, training of farmers, irrigation facilities, and others can create an ecosystem of enhanced returns, the spirit of entrepreneurship and employment opportunities in the farming sector. Also, it is suggested that the seeds and fertilisers should be provided at the subsidised rates to the farmers to generate more yields. Cultivation of these crops are beneficial for soil fertility too with minimum investment. Regarding policy consequences, ensuring support prices and procuring coarse cereals can increase farmers' income and the country's food and nutritional security. Moreover, the current study's findings can be fruitful and will contribute to the existing literature as a reference to similarly placed nations.

ETHICAL CONSIDERATION

There was no ethical issues in the present study as the data was collected from secondary source, Directorate of Economics & Statistics, Ministry of Agriculture, Government of India.

ACKNOWLEDGEMENTS

I am thankful to Directorate of Economics & Statistics, Ministry of Agriculture, Government of India, for providing the data.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Nadkarni, MV. Backward Crops in Indian Agriculture: Economy of Coarse Cereals and Pulses. Economic and Political Weekly. 1986;A113-A118.
2. DeFries R, Chhatre A, Davis KF, Dutta A, Fanzo J, Ghosh-Jerath S, Myers S, Rao ND, Smith MR. Impact of historical changes in coarse cereals consumption in India on micronutrient intake and anemia prevalence. Food and nutrition bulletin. 2018;39(3):377-92.
3. Fu J, Zhang Y, Hu Y, Zhao G, Tang Y, Zou L. Concise review: Coarse cereals exert multiple beneficial effects on human health. Food chemistry. 2020;325:126761.
4. Kaur KD, Jha A, Sabikhi L, Singh AK. Significance of coarse cereals in health and nutrition: a review. Journal of Food Science and Technology. 2014;51(8):1429-41.
5. Government of India. Status paper on coarse cereals, Directorate of Millets Development, Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi; 2014.
6. Ayalew B, Sekar I. Profitability of coarse cereals production in India. International Letters of Natural Sciences. 2015;39.
7. Chatterjee S, Kapur D. Understanding price variation in agricultural commodities in India: MSP, government procurement, and agriculture markets. In India Policy Forum. 2016;3:12-3.
8. Chaudhary MA, Khan MA, Naqvi KH, Ahmad M. Estimates of farm output supply and input demand elasticities: the translog profit function approach [with comments]. The Pakistan Development Review. 1998;1031-50.
9. Dawe D, Timmer CP. Why stable food prices are a good thing: Lessons from stabilizing rice prices in Asia. Global Food Security. 2012;1(2):127-33.
10. Bellemare MF. Rising food prices, food price volatility, and social unrest. American Journal of Agricultural Economics. 2015;97(1):1-21.
11. Chandramouli C, General R. Census of india 2011. Provisional Population Totals. New Delhi: Government of India. 2011:409-13.
12. Sidhu SS, Baanante CA. Estimating farm-level input demand and wheat supply in the Indian Punjab using a translog profit function. American Journal of Agricultural Economics. 1981;63(2):237-46.
13. Altemeier K, Bottema T. Agricultural diversification in Indonesia: price responses and linkganes in the food crop sector, 1969-1988 on outlook to 2000 (Working Paper Series No. 11); 1991.
14. Christensen LR, Jorgenson DW, Lau LJ. Conjugate Duality and the Transcendental Logarithmic funCtion. 1971;255-256.
15. Christensen LR, Jorgenson DW, Lau LJ. Transcendental logarithmic utility functions. The American Economic Review. 1975;65(3):367-83.
16. Binswanger HP, Rosenzweig MR. Behavioural and material determinants of production relations in agriculture. The Journal of Development Studies. 1986;22(3):503-39.
17. Binswanger HP, Singh SK. Wages, prices and agriculture: How can Indian agriculture cope with rising wages?. Journal of Agricultural Economics. 2018;69(2):281-305.
18. Bergman MA. The restricted profit function and the application of the generalised Leontief and the translog functional forms. International Journal of Production Economics. 1997;49(3):249-54.
19. Diewert WE. Applications of duality theory; 1974.

20. Fuss M, McFadden D, Mundlak Y. A survey of functional forms in the economic analysis of production. Histoy of Economic Thought Chapters. 1978;1.
21. Lopez RE. Estimating substitution and expansion effects using a profit function framework. American Journal of Agricultural Economics. 1984;(3):358-67.
22. Kutlu L, Liu S, Sickles RC. Cost, Revenue, and Profit Function Estimates. Handbook of Production Economics. 2020;1-39.
23. Hattink W, Heerink N, Thijssen G. Supply response of cocoa in Ghana: a farm-level profit function analysis. Journal of African Economies. 1998 Oct 1;7(3):424-44.
24. Sidhu SS. Relative efficiency in wheat production in the Indian Punjab. The American Economic Review. 1974; 64(4):742-51.
25. Kumar P. An Application of Generalised Least Squares Estimation of Linear Regression Model with Random Coefficients to Paddy Production Function for Sambalpur District (Orissa). Indian Journal of Agricultural Economics. 1975;30(902-2018-1096):88-103.
26. Chand R, Kumar P. Supply response functions for major crops of Punjab in green revolution period–A profit function approach. Indian Journal of Economics. 1986;67(Part 1):91-109.
27. Meena PC, Kumar P, Reddy GP. Factor demand and output supply of wheat in western India. Indian Journal of Agricultural Economics. 2010;65(902-2016-66763).
28. Kumari B, Chandel BS, Lal P. An econometric analysis of optimality for sustainable paddy production in India. Agricultural Economics Research Review. 2018;31(347-2018-5154):139-45.
29. Jha D, Kumar P. Effect of price changes on cost structure and factor demand: a case study on selected farms in Delhi territory. Indian Journal of Agricultural Economics. 1976;31(902-2018-1279):63-71.
30. Bapna SL, Binswanger HP, Quizon JB. Systems of output supply and factor demand equations for semi-arid tropical India. Indian Journal of Agricultural Economics. 1984;39(902-2018-2260):179-202.
31. Arega M. Supply response of maize in karnataka state-an econometric analysis (Doctoral dissertation, University of Agricultural Sciences, Dharwad).
32. Vishandass AK, Lal RC, Singh J, Sharma A. Inefficiency in Cultivation of Maize on Different Sized Farm in Uttar Pradesh, India. Int. J. Curr. Microbiol. App. Sci. 2018;7(5):635-47.
33. Guha P, Das T. Determinants of Cost Inefficiency of Maize Farming in Different Agro-climatic Regions of Sikkim, India. International Journal of Rural Management. 2020;16(2):177-98.
34. Ogunniyi LT. Profit efficiency among maize producers in Oyo state, Nigeria. ARPN J. Agric. Biol. Sci. 2011; 6(1):11-7.
35. Wongnaa CA, Awunyo-Vitor D, Mensah A, Adams F. Profit efficiency among maize farmers and implications for poverty alleviation and food security in Ghana. Scientific African. 2019;6: e00206.
36. Rahman S, Kazal MM, Begum IA, Alam MJ. Competitiveness, profitability, input demand and output supply of maize production in Bangladesh. Agriculture. 2016;6(2):21.
37. Government of India. Manual on Cost of Cultivation Surveys; 2008b.
Accessed 16 June 2021.
Available:http://mospi.nic.in/sites/default/files/publication_reports/manual_cost_cultivation_surveys_23july08_0.pdf.
38. Government of India. Agricultural Statistics at a Glance; 2019,2020a.
Accessed 16 June 2021.
Available:https://eands.dacnet.nic.in/PDF/At%20a%20Glance%202019%20Eng.pdf.
39. Directorate of Economics and statistics, Department of Agriculture and farmers welfare, Government of India.
Accessed 16 June 2021.
Available:https://eands.dacnet.nic.in/
40. Bos JW, Koetter M. Handling losses in translog profit models. Applied Economics. 2011;43(3):307-12.
41. Kutlu L, Liu S, Sickles RC, Ray SC, Chambers RG, Kumbhakar SC. Cost, revenue, and profit function estimates; 2018.
42. Sadasivam S. Price and non price factors in input use and output supply A case of gram in Uttar Pradesh. Indian Economic Review. 1993;73-83.
43. Wijetunga CS. Rice production structures in Sri Lanka: the normalized translog profit

function approach. Asian Journal of Agriculture and Rural Development. 2016; 6(2):21-35.

44. Junaid S, Ali S, Ali S, Jan AU, Shah SA. Supply response analysis of rice in Pakistan: Normalized restricted translog profit function approach. International Journal of Innovation and Applied Studies. 2014;7(3):825.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/75146