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Assessment of technical efficiency of maize production in Sri Lanka

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Abstract

Maize, being a primary ingredient for food and feed industry, is a vital cereal crop in Sri Lanka. The escalating demand for poultry feed and pre-cooked processed cereal items have significantly increased the demand for local maize production over the last several years and thus, productivity enhancement of local maize producers is an urgent and timely need. This study examines the degree of technical efficiency of maize production in Sri Lanka and its determinants using a stochastic frontier production function. The production function was specified treating maize yield as the dependent variable and seed, fertilizer, agro-chemical, machinery and labor as the independent variables. An inefficiency model was specified to find out potential determinants of technical efficiency. Data for the estimation was gathered from a survey conducted in Anuradhapura, Monaragala and Ampara districts covering 60 farmers from each district. The results revealed that the mean technical efficiencies of maize production in Anuradhapura, Monaragala and Ampara are 59%, 64% and 65% respectively. The technical efficiency of an average maize farmer is 62% implying that there is a large potential to enhance maize production without incurring an additional cost. Primary occupation, education and experience are the major determinants of technical efficiency of maize production. Provision of targeted extension services, facilitation of knowledge and skills sharing between experienced farmers and bringing young farmers in to the maize value chain are recommended to increase the technical efficiency of maize production.

Key words: Maize production, Regional differences, Stochastic frontier analysis, Technical efficiency

Introduction

Maize is the foremost crop in upland agriculture of Sri Lanka with reference to extent, production and contribution to the national economy. It is primarily grown as a rain-fed crop in the *Maha* season both in settled and shifting cultivation. Maize grain is demanded by food and feed manufacturers and green cob is demanded by rural households. Maize sector has achieved some notable growth in the recent years. With the intention of productivity enhancement in maize, high-yielding exotic maize hybrids were introduced to Sri Lanka in 1998 (Kumari *et al*., 2018) and up to 2007, there was a gradual increase in maize productivity while a drastic growth with some fluctuations was reported after 2007. However, at present the local maize production is barely sufficient to meet the demand which is estimated at approximately 400,000 mt per year (Presidential task force, 2015). The trends in cultivated extent, production and average yield of maize in Sri Lanka from year 2002 to 2018 are presented in Annex Figure 1.

The demand for maize is basically derived from the demand for chicken. Chicken meat intake has significantly increased, possibly owing to the disposable income escalation and rise in tourism. It gained the popularity as a better source of dietary protein source in terms of affordability and nutrition. The derived demand for maize has increased substantially due to the recent boost in poultry feed industry followed by the impressive performance of the poultry sector (Wijewantha *et al*., 2010). A substantial quantity of maize is imported annually under a special limited quota permits to meet the momentous surge in maize demand. Importation of maize is bound to be a huge drain on the country’s foreign exchange. Identification of the main technical impediments faced by maize farmers to improve land productivity is crucial owing to the demand escalation for maize and competition for land. Thus, it is important to examine the extent to which the maize production can be increased using existing resources and technology in Sri Lanka. Except for Esham (2014) who evaluated technical efficiency of smallholder maize farmers in Monaragala district using a Stochastic frontier production model, such investigations are minimal in Sri Lanka. This study examines technical efficiency and its determinants of maize production in three major maize growing areas in the country.

Materials and methods

The ratio of output produced to the inputs used by a production unit is a measurement of its productivity (Lovell, 1993). Technical efficiency is an alternative productivity measure. It is measured as the ratio between the observed output and the maximum output. Under the assumption of fixed input it is termed as output oriented technical efficiency and under the assumption of fixed output it is the ratio between the observed input and the minimum input and is termed as input oriented technical efficiency (Porcelli, 2009). This study is based on econometric analysis of output oriented technical efficiency using parametric stochastic frontier model developed by Battese and Coelli (1995) which captures the variations in the effects of noise and the effects of inefficiency. The general form of the stochastic frontier production function model is given in Equation (1).

$$y_i = f(x_i; \beta) exp(v_i) exp(-u_i) \; i = 1, 2, ..., I \qquad (1)$$

Where, y_i is output of the producer *i*; x_i is the input vector of producer *i*; $f(x_i; \beta)$ is the deterministic component of the production function, where β is a vector of technology parameters; $exp(v_i)$ is the stochastic component of the production function which accounts for the statistical noise in the production process, and therefore vi assumed to be independently and identically distributed as N (0, δ2) which are the factors outside the control. The second error component ui which is assumed to be distributed independently of v_i satisfying $u_i > 0$, will capture the possibility of inefficiency in individual producer. The technical efficiency of the producer i which lies between zero and one can be obtained using following equation (Equation 2).

$$TEi_i = \frac{y_i}{f(x_i \beta) e^{vi})} = e^{-ui} \qquad (2)$$

Hence,
Technical inefficiency = $1-TE_i$

The estimation of technical efficiency is a two-stage process. At the first stage, the level of efficiency of each producer was estimated using a Cobb-Douglas stochastic frontier by employing maximum likelihood estimator method using Stata version 13

(Kumbhakar e*t al*., 2015). The Cobb-Douglas stochastic frontier model is shown in Equation (3).

$$ln\, y_i = \beta_0 + \beta_1 ln\, x_{1i} + \beta_2 ln\, x_{2i} + \beta_3\, ln\, x_{3i} + \beta_4\, ln\, x_{4i} + \beta_5\, ln\, x_{5i} + v_i - u_i \quad (3)$$

Where, $_i$ denotes the ith farmer (i= 1,2,…,n) and ln indicates natural logarithm;

y_i = Yield of maize (kg/ac)
x_{1i} = Quantity of seeds used (kg/ac)
x_{2i} = Amount of fertilizer used (kg/ac)
x_{3i} = Cost on agro-chemicals (Rs/ac)
x_{4i} = Cost on farm machinery (Rs/ac)
x_{5i} = Labour use (man days/ac)
$\gamma = \sigma^2 u/\sigma^2$; where $\sigma^2 = \sigma^2_u + \sigma^2_v$ (4)

The variance-ratio parameter γ is bounded between zero and one (equation 4). γ value close to zero implies that the cause for difference between potential yield and actual yield is statistical error whereas, γ value close to one suggests that the yield difference is attributed to inefficient technology usage of the producer (Battese and Corra,1977).

The second stage is the analysis of factors affecting technical inefficiency effects. The inefficiency is associated with farmer specific factors such as socio-economic characteristics. The multiple linear regression model used to evaluate factors affecting technical inefficiency is depicted in equation (5).

$$ui = \alpha 0 + \alpha_1 z_{1i} + \alpha_2 z_{2i} + \alpha_3 z_{3i} + \alpha_4 z_{4i} + \alpha_5 z_{5i} + \alpha_6 z_{6i} + \alpha_7 z_{7i} + \alpha_8 z_{8i} + \alpha_9 z_{9i} + \alpha_{10} z_{10i} + \alpha_{11} z_{11i} + w_i \quad (5)$$

Where; i denotes the ith farmer (i= 1,2,…,n)

u_i = Inefficiency in production
α_0 = Intercept
α_1 - α_{10} = Response parameters
z_{1i} = Age
z_{2i} = Gender (1=if male,0=female)
z_{3i} = Education level
z_{4i} = Experience in maize cultivation
z_{5i} = Household size
z_{6i} = Land ownership (1=if owned, 0=otherwise)

z_{7i} = Occupation (1=if primary occupation is farming, 0=otherwise)
z_{8i} = Type of irrigation (1=if irrigated, 0=rainfed)
z_{9i} = Interaction with extension agents (1=if yes, 0=otherwise)
z_{10i} = Access to agricultural credit (1=if yes, 0=otherwise)
z_{11i} = Received formal training on maize cultivation (1=if yes, 0=otherwise)
w_i = Unobservable random variables

Methods of sampling and data collection

Multi-stage stratified random sampling was used to select the respondents. The first stage involves purposive selection of three major districts cultivating maize in *Maha* season i.e. Anuradhapura, Monaragala and Ampara which covered about 86% of total maize cultivated extent of the country in *Maha* 2016/17. At the second stage, the main Agrarian Services Centres (ASCs) which accounted for more than 50% of the total extent cultivated in *Maha* 2017/18 in each district were chosen. Ultimately, a sample of 60 respondents from each district was randomly selected proportionately to the cultivated extents reported in above selected ASCs. The survey was conducted using the interview method in April and May of 2018 using a pre-tested structured questionnaire.

Results and discussion

Demographic profile

Table 1 summarizes the demographic and household characteristics of the sample. Percentage farmer responses for each district and for the pooled sample are recorded separately.

Majority of the farmers in Anuradhapura district is between 41-60 years old while it is between 31 to 50 years in Monaragala and between 51 to 60 and 31 to 40 in Ampara. Since majority of the sample is in their middle age they have the ability to actively engage in farming. In all districts the preponderance is male. However, it is noted that women participation is low in Monaragala compared to the other two districts. In terms of education, majority of the respondents have secondary education implying they are educated enough to improve production efficiency further. Most of the farmers in all districts were experienced maize producers having cultivated maize for more than 5 years. The prominent household size of the sample was 3 to 5. The descriptive statistics of the parameters used in the stochastic frontier model is shown in table 2 by district.

Table 1. Demographic and household characteristics of the respondents

Variable	Anuradhapura %	Monaragala % (n =60)	Ampara % (n =60)	Pooled sample % (n =180)
Age (years)				
<30	3	0	0	1
31-40	18	30	35	28
41-50	35	35	25	32
51-60	35	23	37	32
>60	9	12	3	7
Gender				
Male	78	97	77	84
Female	22	3	23	16
Level of Education				
Primary	12	20	12	14
Secondary	76	73	83	78
Tertiary	12	7	5	8
Experience				
<5	10	5	12	9
5-15	45	45	38	43
16-25	25	35	30	30
>25	20	15	20	18
Household size				
<2	8	7	16	10
3-5	82	85	82	83
>6	10	8	2	7

Table 2. Descriptive statistics of the parameters used in the stochastic frontier model

Parameter	Anuradhapura	Monaragala	Ampara	Pooled sample
Yield (kg/ha)	4,384	3,731	2,614	3,576
Seed (kg/ha)	14.18	13.74	12.16	13.37
Fertilizer (kg/ha)	531	398	452	467
Agrochemical (Rs/ha)	8,614	5,522	9,422	7,472
Machinery (Rs/ha)	23,623	29,808	24,782	26,072
Labour (mandays/ha)	49	40	62	52

The highest seed rate, fertilizer usage and highest average yield is reported in Anuradhapura district. A significant difference among districts is reported in all the above parameters except for machinery cost. The average yield in the pooled sample (3,576 kg/ha) is close to the national average yield in the particular season (3,800 kg/ha) issued by the Department of Census and Statistics.

Maximum likelihood estimates of the Cobb-Douglas stochastic frontier model

A Cobb-Douglas production function was estimated to identify the determinants of the maize yield in each district. The maximum likelihood estimates of the parameters of the production model are depicted in table 3.

Table 3. Maximum likelihood estimates (MLE) of the parameters of the stochastic frontier model for maize production

Variable	MLE Coefficient			
	Anuradhapura	**Monaragala**	**Ampara**	**Pooled sample**
Intercept (β_0)	0.8038***	8.3846***	3.4896***	2.4222***
Seed (β_1)	-0.0116***	1.1068***	-0.2768	0.8967***
Fertilizer (β_2)	0.6012***	0.0713***	0.2120**	0.2871***
Agrochemical (β_3)	0.0009***	-0.0179***	-0.0028	-0.0043
Machinery (β_4)	0.4060***	-0.4149***	0.2957***	0.2143***
Labour (β_5)	0.1082***	0.3840***	0.1696	0.1162
Diagnostic statistics				
Log likelihood	-29.8938	-21.5004	-31.4158	-116.9675
Variance-ratio(γ)	1.0000	1.0000	0.8988	0.9029
Number of observations	60	60	60	180

*Note: *** Significant at 1% probability level, ** Significant at 5% probability level, * Significant at 10% probability level*

The results reveal that all the variables of the production frontier are significant at $p < 0.01$ in Anuradhapura and Monaragala districts, whereas only fertilizer and machinery are statistically significant in Ampara district. With the exception of agro-chemical and labour all variables are significant at $p < 0.01$ in the pooled sample. The positive coefficient of a variable implies that an increase in the variable would increase the output.

The seed rate shows negative coefficients for Anuradhapura and Ampara which may be due to the use of higher seed rate which would increase the competition among plants for nutrients. The value of variance-ratio for all districts is close to one implying that the total variation in maize yield is mainly because of technical inefficiencies among farmers.

Results in table 4 shows how technically efficient farm household in each district with respect to their farm operations.

Table 4. Technical efficiency estimates across the three districts

Technical efficiency score range	Percentage of farmers (%)			
	Anuradhapura	Monaragala	Ampara	Pooled data
0-20	5	2	0	2
21-40	15	15	13	13
41-60	33	24	20	27
61-80	30	39	45	38
81-100	17	20	22	20
Maximum	100	100	91	91
Minimum	9	7	24	10
Average	59	64	65	62
SD	23.46	22.22	18.04	18.84

The mean technical efficiency of maize production in Anuradhapura, Monaragala and Ampara are 59%, 64% and 65% respectively. However, the results suggest that more than half of the farmers operate above 60% efficiency level other than in Anuradhapura district. As per the results of the pooled sample, on average, the maize production of Sri Lanka can be increased by 38% with the existing resources and technology if the technical inefficiencies are eliminated. The estimates are lower than the estimates of Esham (2014) who reported an estimate of 72%. Similar studies carried out in many other countries on technical efficiency estimation of maize production found parallel or higher mean efficiency estimates. For instance, 64% in Nigeria (Hassan *et al*., 2014), 65% in Laos (Boundeth *et al*., 2012) and Zimbabwe (Mango *et al*., 2015), 74% in Northern Ghana (Abdulai *et al*., 2013), 77% in India (Anupama *et al*., 2005), 79% in Nepal (Adhikari *et al*., 2018), 86% in Ethiopia (Tefaye *et al*., 2014), 91% in Bangladesh (Rahman *et al*., 2012) and 94% in Pakistan (Naqvi, 2013).

Figure 2 illustrates the frequency distribution of farmers according to their efficiency score across the three districts. Majority of farmers of Anuradhapura, Monaragala and Ampara was reported having efficiency score rages of 41-60, 61-80 and 61-80 respectively.

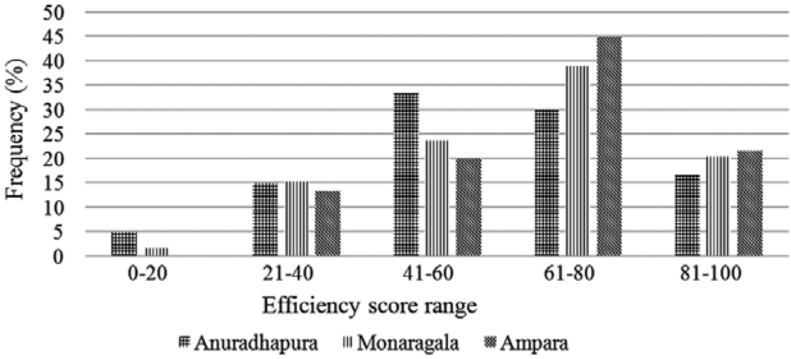

Figure 2. Frequency distribution of farmers according to their efficiency score

The results of the inefficiency model of Anuradhapura district confirmed that education level and age negatively and significantly influenced the inefficiency of farmers (Table 5). The higher level of education would have increased the farmers' managerial skills and decision-making ability. The usage of irrigation water shows positive and significant effect on technical inefficiency, which is unexpected under general condition. However, only 5% of the sample farmers of Anuadhapura have irrigated their maize fields.

According to the results, the extensive experience in maize cultivation and the wider access to agricultural credit would decrease technical inefficiency of maize farmers of Monaragala. The larger household sizes positively influenced the technical inefficiency, whereas youth are more efficient compared to elderly farmers in Monaragala.

Table 5. Determinants of technical inefficiency

Variable	Coefficients of variables			
	Anuradhapura	**Monaragala**	**Ampara**	**Pooled data**
Intercept	1.1241**	0.2292	0.3035	0.4402***
Age	-0.0073*	0.0053**	0.0008**	0.0005
Gender	0.0915	-0.0392	-0.1158	-0.0218
Education level	-0.0463***	-0.0063	-0.0014	-0.0087*
Experience in maize cultivation	-0.0018	-0.0058**	0.0024	-0.0022*
Household size	0.0179	0.0363*	0.0183	0.0219*
Land ownership	0.1412	0.0261	0.0239	0.0286
Occupation	-0.1101	-0.0406	-0.0569	-0.0686**
Type of irrigation	0.2444*	-0.0378	0.1357	0.0042
Interaction with extension agents	0.0176	0.0020	0.0287	-0.0425
Access to agricultural credit	0.0468	-0.0927*	0.0482	0.0177
Received formal training on maize cultivation	0.0175	0.0953	-0.0013	0.0417

*Note: *** Significant at 1% probability level, ** Significant at 5% probability level, * Significant at 10% probability level*

According to the inefficiency model estimated for the Ampara district, only age has statistically significant influence on inefficiency in maize production. There is a positive relationship between the technical inefficiency and the age of the farmer both in Monaragala and Ampara districts as opposed to Anuradhapura district, indicating low adoption of generated technologies by matured farmers. Moreover, the fitted inefficiency model for pooled data suggest that those who involve in farming as the primary occupation, higher level of education and longer years of experience in maize farming lead to a reduction in technical inefficiency of maize production.

Conclusion

Seed, fertilizer and machinery had positive and statistically significant effects on maize production in Sri Lanka. Anuradhapura district has more room for improvement in maize production without incurring an additional cost compared to those in Monaragala and Ampara. Technical efficiency of maize production in Sri Lanka for the *Maha* 2017/18 cropping season have been higher among those who do farming as a primary occupation, possess higher education level and wider experience. In line with the results of this study, it can be suggested that facilitation of sharing the accumulated knowledge and skills of experienced farmers with youth farmers and provision of targeted extension services for less educated farmers would reduce the technical inefficiencies of maize production in Anuradhapura district. Similarly, facilitation of sharing the accumulated knowledge and skills of experienced farmers with inexperienced farmers would contribute to increase the technical efficiency in maize production both in Monaragala and Ampara while provision of targeted extension services for elderly farmers to transmit novel technologies and improvement in access to credit could improve technical efficiency of maize farmers in Monaragala district.

References

Abdulai, S., P. Nkegbe and S.A. Donkoh. 2013. Technical efficiency of maize production in Nothern Ghana. African Journal of Agricultural Research. 8:5251-5259.

Adhikari, S.P., K.P.Timsina, P.R.Brown, Y.N.Ghimire and J.Lamichhane. 2018. Technical efficiency of hybrid maize production in eastern terai of Nepal: A stochastic frontier approach. Journal of Agriculture and Natural Resources. 1(1): 189-196.

Presidential task force. 2015. Food production national programme 2016-2018. 9.

Anupama, J., R.P. Singh and R. Kumar. 2005. Technical efficiency in maize production in Madhya Pradesh: Estimation and implications. Agricultural Economics Research Review. 18(2): 305-315.

Battese, G.E and G.S. Corra. 1977. Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia. Australian Journal of Agricultural Economics. 21: 169-179.

Battese, G.E. and T.J. Coelli. 1995. A model for technical inefficiency effects in a stochastic frontier production function for panal data. Empirical Economics. 20: 325-332.

Boundeth, S., T. Nanseki and S. Takeuchi. 2012. Analysis on technical efficiency of maize farmers in the northern province of Laos. African Journal of Agricultural Research. 7(49): 6579-6587.

Esham, M. 2014. Technical efficiency and determinants of maize production by smallholder farmers in the Monaragala district of Sri Lanka. Mediterranean Journal of Social Sciences. 5:416-422.

Hassan, Y., A.M. Abdullah, M.M. Ismail and Z. Mohamed. 2014. Technical efficiency of maize production in Nigeria: Parametric and non-parametric approach. Asian Journal of Agriculture and Rural Development. 4(4): 281-291.

Kumari, W.M.R., D.C.S.M.I. Wijewardhana, N.A.P.S.G. Upasantha, D.M.J.K. Dissanayake and W.M.W.Weerakoon. 2018. Adaptability and stability testing of CIMMYT maize hybrids in Sri Lanka. Annals of the Sri Lanka Department of Agriculture. 15:89-95.

Kumbhakar, S.C., H. Wang, A.P. Horncastle. 2015. A practitioner's guide to stochastic frontier analysis using stata. Cambridge University press, New York.

Lovell, C. K. 1993. Production frontiers and productive efficiency. In Fried, A. O., Lovell, A. K., and Schmidt, S. S., editors, The Measurement of Productive Efficiency, chapter 1: 3-67. Oxford University Press.

Mango, N., C. Makate, B.H. Mlambo, S. Siziba and M. Lundy. 2015. A stochastic frontier analysis of technical efficiency in smallholder maize production in Zimbabwe: The post-fast-track land reform outlook. Cogent Economics and Finance. 3: 1117189

Naqvi,A., A. Syed and M. Ashfaq. 2013. Technical efficiency analysis of hybrid maize production using translog model case study in district Chiniot, Punjab. Agricultural Sciences. 4(10): 536-540.

Porcelli, F. 2009. Measurement of technical efficiency: A brief survey on parametric and non-parametric techniques. University of Warwick.https://pdfs.semanticscholar.org/12b1/0d8c848c0f8ace5ac508493504789724bfc1.pdf (Accessed on 17.08. 2019)

Rahman, S., M.S. Rahman and M.H. Rahman. 2012. Joint determination of the choice of growing season and economic efficiency of maize in Bangladesh. Journal of the Asia Pacific Economy. 17(1): 138-150.

Tefaye, W., H. Beshir. 2014. Determinants of technical efficiency in maize production: The case of smallholder farmers in Dhidhessa district of Illuababora zone, Ethiopia. Journal of Economics and sustainable development. 5(15): 274-284.

Wijewantha, P., K.A.C.H.A. Kothalawala, U.K.M. Wickramasinghe and R.K. K. Rannasinghe. 2010. Livestock statistical bulletin, Department of Animal Production and Health. Available from: http://www.daph.gov.lk/ web/mages/df/ stb201031. pdf.