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Measuring technical efficiency of the cauliflower cultivation in Bangladesh: A case study on Dhaka district

Fazlul Hoque[1]*, Sharmin Afrin[1], Asma Akter[1], Moriom Khatun[1], Tahrima Haque Beg[1], Tanjina Afrin[1] and Karma Yoezer[2]

[1]Sher-e-Bangla Agricultural University, Bangladesh. [2]Sherubtse College, Royal University of Bhutan, Bhutan.
**E-mail: fazlulhoque1991@gmail.com*

Abstract

The research was conducted to explore the technical efficiency of the cauliflower production in Savar and Keraniganj Upazila of Dhaka district, Bangladesh by applying the stochastic production frontier approach. Primary data were collected from 120 households cultivating the cauliflower following the face to face interview by using a structured questionnaire. The estimated results revealed that the mean technical efficiency was 85 % which implies that the household cultivating the cauliflower can increase the revenue by 15 % at given level of resources. Lastly, the inefficiency model suggested that the seedlings of improved varieties, more access to market information, and better training and extension service can minimize the farm level inefficiency.

Key word: Cauliflower, technical efficiency, farmer, agriculture, Bangladesh

Introduction

Agriculture is one of the predominant driving forces for the economy of Bangladesh and its contribution to fulfilling the national macroeconomic targets such as employment of labor force, reduction of hunger rate, extinction of poverty and industrialization are remarkable. For instance, Agriculture captures 14.10 % GDP and absorbs 40.7 % of total manpower in Bangladesh (BBS, 2019). Bangladesh is blessed with 56,977 sq.miles equivalent to 14.3 million hectares while about 59.86 % is accessible for agricultural use (BBS, 2018). The land of Bangladesh is very fertile where various types of crops are grown easily. Major crops such as rice, potato, wheat, sugarcane, jute, oilseed, tea, various fruits and vegetables are grown across the country. Cauliflower (*Brassica oleracea* var. botrytis) is one of the popular vegetables mainly cultivated in winter season in Bangladesh. It is cultivated more or less over the country prevailing the suitable climate of cool daytime temperatures 21-29 °C, with sufficient sun, moist soil conditions high in organic matter and sandy soils but most of the cauliflower is produced in the region of Dhaka, Jessore, Rajshahi, Rangpur, Tangail and Kustia. It is an annual plant that is reproduced by seed. Usually, only the head is eaten – the edible white flesh sometimes called "curd" (Vincent *et al.*, 2017). Cauliflower contains about 92 % water, 5 % carbohydrates, 2 % protein, negligible fat, folate, and vitamin having a high nutritional density. It has also several non-nutrient phytochemicals, usually found in the cabbage family which are beneficial to human health. A high consumption of cauliflower is assumed to reduce the risk of aggressive prostate cancer.

Global production of cauliflowers (combined with broccoli) was 25.2 million tons, led by China and India which, combined, had 73 % of the world total (FAOSTAT, 2016). The production of vegetables including cauliflower is increasing day by day in Bangladesh. For instance, the total vegetables production has increased by 22.73 % from 10.52 million metric tons in 2010-11 to 12.912 million metric tons in 2017-18 whereas the production of the cauliflower has increased by 63.09 % within same time.

According to Bangladesh Bureau of Statistics (BBS, 2019), annual production of vegetables was 12.912 million metric tons of which 0.274 million metric tons was cauliflower. Thus, the production of cauliflower captures a remarkable share of the total vegetable production in Bangladesh. About 100 types of fresh horticultural crops are being exported from Bangladesh to more than 40 countries in the world. Export earnings from fresh fruits and vegetables have significantly increased from $ 51 million in FY2008-09 to $ 125 million in FY2015-16 (Hortex, 2020). Hence the government of Bangladesh is emphasizing on the production and export of high value agro-commodities especially horticultural crops through diversification of produces and market expansion. Since, the demand of the cauliflower is increasing day by day in domestic and foreign market, the Government of Bangladesh has prioritized to increase the production of cauliflower by providing subsidy to the farmers on different inputs such as seeds, fertilizer, irrigation *etc.* to achieve self-sufficiency in cauliflower production.

The production of agriculture sector has experienced the tremendous growth due to introduction of improved variety seed, hybrid seed, chemical fertilizers, pesticides, easing the irrigation facilities. Beside food grain like rice, wheat, maize *etc.* the government of Bangladesh has emphasized to increase the production of vegetables considering the nutritional value and higher return in the country for achieving the food self-sufficiency. Still per capita consumption of vegetable is 166.1 g daily instead of 200 g required (Hoque *et al.*, 2019). This indicated that we must increase the vegetables production for meeting up the domestic demand and exporting the vegetables for earning the foreign currency which will create an employment opportunity and ultimately reduce the poverty in Bangladesh. Although, the production of cauliflower has increased significantly but the productivity is low due to following the traditional farming practices, lack of modern variety and high yield variety (HYV). For example, productivity of cauliflower in Bangladesh is of 11.41 metric tons/ ha whereas, cauliflower productivity for hybrid variety is of 40 metric tons/ha in India (Reddy, 2019).

Few empirical studies were conducted on technical efficiency of cauliflower and vegetables production in Bangladesh and abroad. Specifically, Mitra and Yunus (2018) assessed the technical efficiency and sources of inefficiency among the household cultivating tomato in Mymensingh district, Bangladesh. Hoque *et al.* (2019) estimated the technical efficiency and sources of inefficiency of bottle gourd and brinjal cultivation in Dhaka district, Bangladesh. Rajendran (2014) measured the technical efficiency of fruit and vegetable producers in Tamil Nadu, India. Rajendran *et al.* (2015) investigated the technical efficiency of the traditional African vegetable production in Tanzania. Shaheen *et al.* (2011) studied on technical efficiency of off-season cauliflower production in Punjab, Pakistan. Dahal *et al.* (2019) estimated the technical efficiency of cauliflower production in suburb of Kathmandu valley, Nepal; Sugianto (1985) assessed the production efficiency of cauliflower in Indonesia. Wahid *et al.* (2017) measured the technical efficiency of tomato growers in Malakand, Pakistan. Abdulrahman *et al.* (2018) studied on the economics and efficiency of the rain-fed cabbage production in Nigeria. The findings of these studies were not similar and it showed that seed, labor, fertilizer and irrigation affected the technical efficiency of vegetable production. In addition, socioeconomic conditions such as age, education, farm holding size, seedling variety, and training service had significant impact on inefficiency. On the other hand, there is no single study on measuring the technical efficiency on cauliflower production in Bangladesh. Given this fact, this study aims to estimate the technical efficiency of cauliflower cultivation and identify the determinants of cauliflower production. Finally, the study will figure out the sources of inefficiency cultivating the cauliflower.

Theoretical Framework of Stochastic Frontier Analysis (SFA)

Aigner *et al.* (1977), Meeusen and Van den Broeck (1977) independently proposed the stochastic production or cost frontier models. Stochastic frontier model suits with the specific parameterizations of the inefficiency term and can match the stochastic production frontier or cost frontier model. Suppose that a farmer has a production function for a single output without any inefficiency (maximum possible feasible production frontier) as

$$Yi = f(Xi, \boldsymbol{\beta}) \qquad (1)$$

In Equation (1), Yi indicates the yield of the i-th farm, X_i denotes variable inputs with K inputs used by farmer to produce the cauliflower and β indicates (Kx1) vector of technology parameters to be estimated.

Stochastic Frontier Approach considers that farmer (farm) produces less than maximum feasible production frontier from proposed due to the degree of inefficiency. Stochastic production function can be written by adding error term for inefficiency as

$$Yi = f(Xi, \boldsymbol{\beta}) \exp(\varepsilon_i) \qquad (2)$$

Where, ε_{ii} is composed of two independent elements v_i and u_i, such that $\varepsilon_{ii} = v_i - u_i$; u_i denotes one sided error while v_i is two sided error term. The random component v_i is assumed to be identically and independently distributed as N (0, σ_v^2) and is also independent of u_i. This random error represents random variations in output due to those factors are impossible to control for farmer such as agro-climate, natural disasters, sudden failure of machines and quality of variable inputs (such as seed, fertilizer, manure, insecticides, *etc.*) as well as the effects of measurement errors in the output variable, statistical noise and omitted variables from the functional form (Aigner *et al.,* 1977).

u_i is nonnegative random variable that represents the stochastic shortfall of outputs from the most efficient production. u_i is the one-sided disturbance form used to represent technical inefficiency and are assumed to be independently and identically distributed with the half normal truncated distribution as $N^+(0, \sigma_u^2)$ also independent of v_i (Kumbhakar and Lovell,2000).

Maximum Likelihood Estimation (MLE) technique is employed to estimate the parameters (*β, σ, γ*) of stochastic frontier. The variance of the parameters can be estimated as following way:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2;\ \gamma = \frac{\sigma_u^2}{\sigma^2} = \frac{\sigma_u^2}{(\sigma_u^2+\sigma_v^2)}$$

FRONTIER version 4.1 software can be used to estimate all parameters of the SFA of the maximum likelihood function (Coelli, 1996b). This software estimates the $\gamma = \sigma_u^2/\sigma_s^2$ parameter, which takes a value between zero (0) and one (1). When, $\gamma = 0$ denotes that deviations from the production frontier are due to noise. whereas, $\gamma = 1$ represents that deviation from the frontier are due to technical inefficiency.

The efficiency of a production unit involves the comparison between observed and optimal amount of its output and input (Lovel, 1993). The ratio of the observed output of the *i*-th farm relative to the potential output estimated by equation (3.1) provides the technical efficiency of *i*-th farm. Hence, technical efficiency denoted by TE_i is given by:

$$TE_i = \frac{Actual\ Output(Y^0)}{Maximum\ Fesible\ Output(Y^m)} \qquad (3)$$

$$TE_i = \frac{f(X_i,\beta)exp(v_i-u_i)}{f(X_i,\beta)exp(v_i)} = E\{exp(-\hat{u}_i)\} \qquad (4)$$

Material and methods

The study was conducted in Savar and Keraniganj regions of Dhaka district in Bangladesh. A structured questionnaire focusing on quantities of input-output, price of input-output, socio-economic conditions of the farmers were used to collect data of 60 from each region through face to face interview and 120 was the total sample size for the analysis. Data were collected from the respondents following the 2019-2020 cauliflower cropping season. The collected data were subsequently processed, tabulated and analyzed for the purpose of the study. The stochastic production frontier with inefficiency model assuming a Cobb-Douglass functional form was applied to estimate the technical efficiency and determinants of technical inefficiency among the households cultivating the cauliflower. The stochastic production frontier was estimated using a single stage maximum likelihood function estimation procedure by the Frontier Version 4.1 (Coelli, 1996).

Empirical Model: Following Coelli (1996), the stochastic production frontier with a Cobb-Douglas functional form was employed to estimate all parameters in single step maximum likelihood estimation.

$$InY = \beta_0 + \beta_1 lnX_1 + \beta_3 ln\, X_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + exp\,(v_t - u_t)$$

Where, Y= Revenue (Tk); X_1= Labor cost; X_2= Seedling Cost; X_3= Fertilizer Cost; X_4= Pesticides Cost; X_5= Irrigation Cost;

Inefficiency model: The inefficiency model (U_i) is defined by:

$$U_i = \delta_0 + +\delta_1 R_{1i} + \delta_2 R_{2i} + \delta_3 R_{3i} + \delta_4 R_{4i} + \delta_5 R_{5i} + \delta_6 R_{6i}$$

Where, U_i = Technical inefficiency score; R_1 = Education (Schooling years); R_2 = Access to input and output market Information (yes=1, otherwise = 0); R_3 = Training and extension advisory service (yes=1, otherwise = 0); R_4= Variety (high yielding variety =1, Local variety =0)

Results and discussion

Benefit Cost Ratio (BCR) for the cauliflower cultivation in Dhaka region is presented in Table 1. According to the estimated BCR of 2.34, the cauliflower cultivation is substantially profitable in Dhaka region. Labor, seedling/seed, fertilizers, irrigation and pesticides are major inputs for cauliflower cultivation (Akter *et al.*, 2016; Hoque *et al.*, 2018; Shaheen *et al.*, 2011; Rajendran *et al.*, 2015; Dahal *et al.*, 2019).

Table 1. Benefit Cost Ratio (BCR) for the cauliflower production per acre

Cost	Mean	Percentage of cost
A. Variable Cost		
Labor cost (Tk)	15000	20.44
Seed cost (Tk)	14500	19.76
Tillage cost (Tk)	4800	6.54
Fertilizer cost (Tk)	13540	18.45
Pesticide cost (Tk)	3200	4.36
Irrigation cost (Tk)	5500	7.50
Transportation cost (Tk)	4800	6.54
Others	2000	2.73
Total	63340	86.33
B. Fixed Cost		
Land use cost (Tk per season)	7500	10.22
Interest on operating cost	2533.6	3.45
Total	10033.6	13.67
Price of output (Tk/ piece)	15	
Output (Nos)	11460	
C. Revenue	171900	
Gross Margin (C-A)	108560	
Net Margin [C-(A+B)]	98526.4	
BCR [C/ (A+B)] (Undiscounted)	2.34	

Source: Author Survey, 2019.

Estimates of Cobb-Douglass production frontier through MLE for total 120 respondents of the study area are presented in Table 2. The sigma-Squared (σ^2) was found 0.233 and statistically significant at the 5 percent probability level. Again, the value of gamma parameter (γ) was found 0.88 and was significant at 1 percent probability level. This means that 88 percent deviation in actual profit from profit frontier among the farms happened because of farm-specific characteristics rather than random variability.

The labor cost was affecting the gross return at 1 percent level of significance. This finding indicates that higher cost of labor ensures to the higher level of the farm revenue and *vice versa*. Labor cost is one of the major cost items which includes all activities starting from land preparation to ultimate sale of the cauliflower. Consequently, more labor cost means higher number of labor required for better land preparation, carefully weeding of field, better management of insects and pests, careful harvesting of cauliflower which ultimately earn higher level of the revenue. Thus, higher cost of labor leads higher level of technical efficiency. The result is consistent with other researchers (Shaheen *et al.*, 2011; Rajendran *et al.*, 2015; Hoque *et al.*, 2019; Dahal *et al.*, 2019).

Table 2. Estimation of the Cobb-Douglass Stochastic Production Frontier

Variables	Coefficient	Standard Deviation	t-ratio
Constant	0.309	0.05	6.18
Labor cost	0.330	0.083	3.976
Seed cost	0.139	0.048	2.892
Fertilizers cost	0.215	0.128	1.68
Pesticides cost	0.088	0.094	0.936
Irrigation cost	0.368	0.095	3.869
Sigma squared	0.233	0.026	8.962**
Gamma	0.88	0.064	13.750**

Log Likelihood Value =64.89

The coefficient of the seed cost was of 0.139 and statistically significant with the farm revenue at 5 percent probability level. It means the households cultivating the cauliflower by more cost of the seed are more technically efficient than the households spending less in seed. Higher seed cost incurs for more amount of seed and better-quality seed. Better quality seed germinates more in percentage, grows well, tolerate the biotic and abiotic stress easily and finally yields better. Hence, the more seed cost promotes to more farm revenue by higher level of technical efficiency. The similar finding was reported by Shaheen *et al.* (2011); Rajendran *et al.* (2015); Hoque *et al.* (2019); Dahal *et al.* (2019).

Similarly, the fertilizer cost had a positive and statistically significant relationship with the gross revenue. The result suggests that higher cost of fertilizers help the households cultivating the cauliflower to earn the more gross margin and *vice-versa*. Higher cost of fertilizers indicates more amount of fertilizers and better-quality fertilizer application in the field which accelerates more production of cauliflower (Shaheen *et al.*, 2011; Rajendran *et al.*, 2015; Hoque *et al.*, 2019)

Finally, the coefficient of irrigation cost was positively related to the farm revenue and critically significant at 1 percent level. The outcome denotes that higher cost in irrigation leads to a higher level of the gross revenue by cultivating the cauliflower in Dhaka region and *vice-versa*. Irrigation is one of the essential elements to cultivate the cauliflower because it improves water condition in soil, control soil temperature, dissolves nutrients and makes them available to plants and it is necessary to irrigate the field after planting the seedling till harvesting the cauliflower. Consequently, irrigation facility directly affects the yield of the cauliflower. Finally, the households cultivating the cauliflower with more irrigation cost earn more farm revenue than other. The finding is supported by Shaheen *et al.*, 2011; Hoque *et al.*, 2019.

The Log-Likelihood Ratio (LR) test was carried out to test the hypothesis. LR= - 2 {log [L (H_0) – log [L (H_a)]} formula was used to carry out the likelihood ratio test. The null hypothesis was that there was no technical inefficiency in the Cobb-Douglass

Table 3. Test of hypothesis

Null hypothesis	Log Likelihood (H_o)	Log likelihood (H_a)	No. of Restrictions (df)	Test statistics (LR)	Critical value (5 %)	Decision
H_0: $\gamma = 0$	-96.70	-64.89	1	63.6	2.71	Rejection

Table 4. Estimation of Inefficiency Model

	Coefficient	Standard deviation	t-ratio
Constant	1.195	0.303	3.944**
Age	0.074	0.092	0.804
Education	-0.023	0.019	-1.21
Training & Extension service	-0.352	0.217	-1.622*
Access to Market information	-0.416	0.172	-2.418**
Variety	-0.475	0.154	-3.084***
Sigma Squared	0.233	0.026	8.962**
Gumma	0.880	0.064	13.750**

Log likelihood value =64.89

production frontier. The calculated Log likelihood Ratio (LR) was 63.6 which is higher than the tabulated value (2.71) and significant at 5 % probability level that means the null hypothesis is rejected and technical inefficiency exists in the Cobb-Douglass production function.

The sources of technical inefficiency among the households cultivating the cauliflower is presented in Table 4. The objective of estimating inefficiency model was to identify the sources of inefficiency for the policy recommendation. Galawat and Yabe (2012) mentioned that the direction of coefficient in the inefficiency model is noteworthy in describing the obtained level of efficiency of the farm. A coefficient with negative sign indicates that the factor minimizes the inefficiency, while coefficient having positive sign means it accelerates the inefficiency. The coefficients of education, training and extension service, access to market information, variety were negative which implies these factors reduce the technical inefficiency. On the other hand, the coefficient of the age of the farmers was positive which indicates increase in the inefficiency.

The coefficient of the training and extension service was -0.352 and affected the technical inefficiency at 10 % level of significance. It implies that farmers who receive training and extension service on the cauliflower farming are more efficient to earn the gross revenue than those do not participate in training session. Hoque *et al.* (2019) reported that training and extension service introduces the farmers with the advanced technologies, modern farming practices which ultimately increases productivity and efficiency. Similar result was found by Mitra and Yunus (2018) and Dahal *et al.* (2019).

Similarly, the coefficient of access to market information was of -0.475 and statistically significant with technical inefficiency at 5 % probability level. This suggests that the households having more access to market information are technically more efficient than other. Adequate access to market information supports farmer to identify the proper markets from where farmers can purchase the better quality of farm inputs at reasonable price and can sell their output at fair price which ultimately ensures reasonable profit. That's why the market information affects the technical efficiency significantly. The identical finding was reported by Saysay (2016).

Lastly, seed variety affected the technical efficiency at 5 % level of significance. The finding indicates that farmers using the modern high yield variety seed or seedling are more efficient than the farmers using the local variety seed or seedling for cultivating the cauliflower. The finding was consistent with other workers (Ali *et al.*, 2014; Hoque *et al.*, 2019; Mitra & Yunus., 2018)

Table 5 illustrates the frequency distribution of farm-specific technical efficiency scores of cauliflower cultivating households for Dhaka region. The result showed that the profit efficiency ranged from 26 to 94 % having the average efficiency score of 85 %. Data indicate that a considerable amount of revenue loss occurred due to the fact of the existence of inefficiency in utilization of available resources. The cauliflower cultivating households can be efficient by improving 15 % revenue from given level of resources and technologies. However, the least efficient household must increase the efficiency score of 74.46 % [(1.00-0.24/0.94)*100] by using of farm resources if the household desires to accomplish the efficiency of the best household in the study area and must gain efficiency score of 76 % [(1.00-0.24/1.00)*100] to operate on the frontier. Also, the most efficient household must gain the efficiency score of 6 % [(1.00-0.94/1.00) *100] to operate on the frontier.

Table 5. Technical efficiency

Range	Frequency	Percentage
0.21-0.3	10.00	8.33
0.31-0.4	9.00	7.50
0.41-0.5	11.00	9.17
0.51-0.6	9.00	7.50
0.61-0.7	15.00	12.50
0.71-0.8	18.00	15.00
0.81-0.9	33.00	27.50
0.91-1.00	15.00	12.50
Total	120.00	100.00
Maximum	0.94	
Minimum	0.26	
Standard Deviation	0.18	
Mean	0.85	

Source: Author Survey, 2019.

Policy recommendation: Based on the study, we can recommend few suggestions for the policy makers to upgrade the technical efficiency. The study showed that (i) the choice of seedling variety affected the technical efficiency significantly. The productivity of the cauliflower is extremely lower than other countries due to cultivation of the local variety. For instance, productivity is of 4.62 metric tons/ acre in Bangladesh (Sharmin *et al.*, 2018) while average yield of the cauliflower in India is 19.17 tons/ ha (Kumari *et al.*, 2020). The government of Bangladesh can emphasize the responsible agencies to develop the high yielding variety of cauliflower and disseminate to the grass root level in Bangladesh at reasonable cost. (ii) access to the market information and agricultural market played a vital role in determining the technical efficiency. Better access to market and information lead to higher level farm profitability. If farmers get an updated information on market, they can decide to sell their commodities at the market where higher price is going on and can purchase the better quality of farm inputs such as seed, fertilizers, pesticides *etc.* Thus, access to market and information promotes the technical efficiency. Department of Agricultural Marketing (DAM), Ministry of Agriculture can monitor the agricultural market to ensure the reasonable price of the cauliflower and the price of the seed, fertilizer, pesticide *etc.* (iii) training and extension service influenced the technical efficiency substantially in the cauliflower cultivation. The department of agricultural extension (DAE) must arrange the training sessions for the farmers cultivating the cauliflower to introduce the modern farming practices by adopting the latest technology such as improved seed, bio fertilizer, integrated pest management (IPM) *etc.*

The inefficiency model suggested that seedling, variety, access to market information, and training and extension service can reduce the inefficiency. Hence, the government can enforce the responsible organization to develop the high yielding variety (HYV) and disseminate the improved variety of the cauliflower at the farm level by effective monitoring of the department of agricultural extension. Finally, the agricultural commodity market must be monitored to ensure the reasonable price of the cauliflower and relevant farm inputs for increased farm profitability.

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