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Determinants of tomato farmers efficiency in Mymensingh district of Bangladesh: Data Envelopment Analysis approach

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Abstract

Tomato is one of the major vegetables in Bangladesh that experienced massive productivity growth after independence. Nevertheless, farmers are struggling to find out optimal input combination in their farm that causes inefficient input use. Therefore, this study estimated the factors affecting efficiency of tomato farmers in Mymensingh of Bangladesh. Input oriented Data Envelopment Analysis (DEA) was employed for measuring efficiency while Tobit regression model was used to estimate the factors affecting efficiency. A total of 60 tomato farmers were selected using random sampling technique. Mean technical efficiency for tomato farmers was 0.83 implies that tomato farmers can reduce their input use by 17%. Education, training and high yielding variety adoption had positive effect on efficiency while age of tomato farmer's had negative effect on efficiency. Efficiency increased with the farmer's education, training and variety adoption. Farmer's adopting local high yielding variety was more efficient than that of exotic high yielding variety. In addition, efficiency of farmers reduced with their age. Improvement of tomato farmer's efficiency is possible if farmers received education, training and local high yielding variety.

Introduction

World vegetable production has boosted up and witnessed about 330% growth within last 50 years (FAOSTAT, 2016; Weinberger and Genova, 2005). Among different vegetables, tomato production has reached in 177042 thousand tons in 2016 that occupies about 60% of total fresh vegetable production in the world (Mitra and Prodhan, 2018). This massive productivity growth amplifies incomes for laborers, empowered women and created new employment opportunities particularly for landless farmers in developing countries (SOFA team *et al*., 2011; Weinberger and Genova, 2005). Immense production of tomato and its nutritional importance is the blessing for a developing country like Bangladesh. History of Tomato farming in Bangladesh is not apparent. Probably it was evolved in South America over millions of years ago and arrived in Asia in early 19th century (Vegetable Facts, 2018). Production of tomato has increased in Bangladesh about 6.5 times after 1971. Massive productivity growth within last 50 years is presented by upward sloping curve (Figure 1).

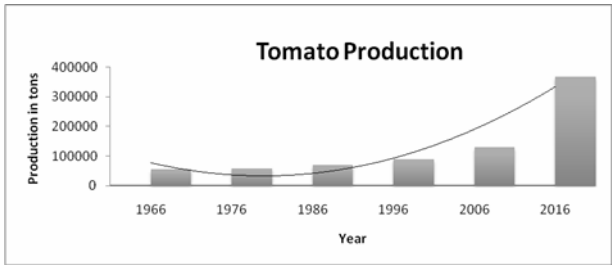

Figure 1. Tomato production in Bangladesh

Tomato production has experienced tremendous growth in last 10 years because of high yielding varieties adoption, timely use of pesticides, training and extension facilities. Although tomato is a winter vegetable, Bangladesh Agricultural Research Institute has developed two new varieties namely BARI HYBRID TOMATO - 3 & 4 which is produced in summer season. The average yield of BARI hybrid summer tomato is 32.78 ton per hectare (Karim *et al*., 2009). Nonetheless, tomato farmers are struggling to find out optimal combination of inputs that retards the productivity growth and causes inefficient input use in tomato farming. Overdose of inputs such as pesticides and fertilizer is harmful and unhygienic for soil, environment and human health (Curl *et al*., 2003). These problems of inefficient input use exacerbate because of lack of training, extension services, education, and experience.

Several studies have been conducted on tomato production over the world. Efrance *et al*. (2016) estimated the determinants of technical efficiency for the open field tomato farmers in Kenya. Djidonou *et al*. (2013) determined the effects of different irrigation regimes and N rates on yield, irrigation water use efficiency, and N use efficiency of grafted tomato plants grown with drip irrigation in sandy soils of north Florida. Murthy *et al*. (2009) studied the factors affecting technical efficiency of tomato farmers in Karnataka, India. In spite of these studies, factors affecting efficiency of tomato farmers have not been carried out in Bangladesh. Therefore, this study tried to estimate the efficiency level of tomato producer and factors affecting efficiency.

Materials and Methods

Sampling procedure and data description

Mymensingh district was selected purposively because of concentrations of tomato farmers. Tomato production has increased about 98% within last 8 years in Mymensingh that becomes 6800 MT in 2014-15 (BBS, 2015-16). A total of sixty sample respondents of tomato farmers were selected by using random sampling techniques. Cross-section data were collected from these respondents using questionnaires and direct interview method. Information was collected about input used in production process, the output produced, socio-economic characteristics of farmers, cost of inputs and return from output. Input and output variables were used for the measurement of technical efficiency (Table 1). Total output of tomato farms was the output variable which was measured in kg per hectare. Input variables were labor man days, seed cost, fertilizer cost, pesticides cost, irrigation cost, land rent and power tiller cost which were measured in Bangladeshi taka. Labor input was the summation of both family and hired labor and eight hours are considered as one man day (Khan, 2017; Iliyasu and Mohamed, 2016; Alam *et al., 2012*). Because of quality and price variation, different input's costs were used for efficiency measurement instead of quantity of inputs.

Table 1. Variables used for efficiency measurement

Variables used for efficiency measurement	Units / hectare
Total output of tomato farms	Kg
Quantity of labor	Man days
Cost of seed per year	Taka
Cost of fertilizer per year	Taka
Cost of pesticides per year	Taka
Cost of irrigation per year	Taka
Land rent	Taka

Different socio-economic factors that may influence technical efficiency are presented in table 2. The determinants of efficiency were age, education, family members, training, experience, extension service and high yielding variety adoption. Age, education and experience were presented in years while Training, extension service and high yielding variety adoption were presented as dummy. Farmers who had received training and had contract with extension services provider were denoted by 1 and who has no training and extension services denoted by 0. Farmer's who adopted local high yielding tomato variety (BINA tomato-2, BINA TOMATO-3, BINA TOMATO-4, BARI F1 Tomato-4 and BARI F1 Tomato-5) denoted as 1 and 0 for other exotic high yielding variety adopters. Besides these, farmers were using different exotic high yielding varieties like Lali, Nayak, Delta, Mintoo super and Success (Ali *et al*., 2014) denoted as 0.

Table 2. Variables used for inefficiency factors

Variables used as inefficiency factors	Units
Z_1= Age	Years
Z_2= Education	Years of schooling
Z_3 = Family member	Number
Z_4 = Experience	Years
Z_5= Training	Dummy(1 = if received and 0= for not received)
Z_6= Extension Service	Dummy(1 = if taken and 0= for not taken)
Z_7 = Variety adoption	Dummy (1 = if local high yielding variety adopted and 0 = for high yielding exotic variety adoption)

Analytical Technique

Data Envelopment Analysis (DEA) was used to measure the efficiency and Tobit regression was employed to find out the determinants of technical efficiency. DEA is a powerful tool for measuring efficiency which was first introduced by Charnes, Cooper, and Rhodes in 1978. DEA has huge application in the field of agriculture (Khoshroo *et al*., 2013; Poudel *et al.* 2012; Murthy *et al*., 2009; Bravo-Ureta & Pinheiro, 1997). DEA can handle multiple inputs and multiple outputs. Input oriented variable returns to scale was used to analyze the technical efficiency of tomato farms. Tomato farms were different in size and production technology varies from farm to farm. It is much easier to control inputs than controlling outputs. Therefore, input-oriented variable returns to scale is better than output-oriented model. Variable returns to scale and input minimization can be described as:

VRS:

Minθ

S.T.

$$\sum_{k=1}^{k} \lambda_k x_{ik} \leq \theta x_i^0, \; i = 1,\ldots\ldots,m$$

$$\sum_{k=1}^{k} \lambda_k y_{ik} \geq \theta x_i^0, \; i = 1,\ldots\ldots,n$$

$$\sum_{k=1}^{k} \lambda_k = 1$$

$$\lambda_k \geq 0, \; k = 1,\ldots\ldots, k$$

Here,

K = observed DMUs (k=1,…,K); m = different inputs used (i=1,…,m); n = different outputs produced (j=1,…,n); $x_{ik} = (x_{1k}, \ldots, x_{mk}) \in \Re_+^m$ = Input vector; $y_{jk} = (y_{1k}, \ldots, y_{nk}) \in \Re_+^n$ = Output vector; λ^k = Parameter set.

Few earlier studies used Tobit regression model for investigating the factors affecting efficiency (Alam, 2011; Nielsen, 2012; Zongli *et al*., 2016). Efficiency is

ranged from 0 to 1 and this Tobit model is better for this analysis (Prodhan, 2015). The empirical Tobit regression is as follows:

$$Y = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + e$$

Where,

Y= Efficiency; α_0 = Intercept; β = Coefficient; X_1 = Training (dummy); X_2 = Education (Years of schooling); X_3 = High yielding variety adoption (dummy); X_4 = Experience (Years); X_5 = Age (years); X_6 =Extension services (dummy); X_7 = Family member (number); and e = error term.

R-software was employed to measure the efficiency of tomato farmers while STATA-14 was used for estimating Tobit regression.

Result and Discussion

Summary Statistics

Summary statistics of output, input and socio-economic variables of tomato farmers were showing the substantial variation among tomato farmers input costs and production (Table 3). Result found that mean yield of tomato farmers was 21067 kg per hectare ranging from a minimum of 9000 kg to as maximum as 35000 kg (Table 3). Baree (2012) found that average yield of BARI hybrid tomato was found 32780 kg per hectare. Fertilizer was the major input for tomato production and cost of fertilizer per hectare was Tk. 50456. Irrigation cost was the second most important variable cost (Tk. 19257) items of tomato farmers. Timely irrigation for tomato is indispensible for high productivity (Djidonou *et al*. 2013; Zotarelli, 2008).

Table 3. Descriptive statistics for tomato farmers

Variables	Tomato			
	Mean	SD	Min	Max
Yield (kg per hectare)	21067	5718	9000	35000
Quantity of labor (man days per hectare)	15	6	5	40
Cost of fertilizer ([1]Tk. per hectare)	50456	8428	26000	66690
Cost of irrigation (Tk. per hectare)	19256	2932	9700	23712
Cost of power tiller (Tk. per hectare)	4047	839	1500	5434
Cost of seed (Tk. per hectare)	8396	4493	2500	15561
Cost of pesticide (Tk. per hectare)	6122	1140	3000	8398
Land rent (Tk. per hectare)	88423	8597	64000	98800
Experience	11.08	1.66	8	16
Education	8.97	2.29	4	16
Family member	5.73	1.23	3	8
Age	41.7	16.38	20	67

[1]Tk is Bangladeshi currency and its conversion is US$1 = Tk. 78 approximately

Most of the farmers had more than 11 years' experience on tomato farming and middle age (Table 3). Average family size was 5.73 which were greater than average family size of Bangladesh (BBS, 2015-16). Though large family size increases the dependent or non-earning members, they can work as a family labor that will reduce the hired labor cost. Peter and Susan (2014) found that older farmers had a larger family size and young members of this family contributed to the farm as a labor. Mean years of schooling or education was 9 years which was better in the perspective of Bangladesh.

Technical efficiency

Technical efficiency of tomato under input oriented variable Returns to Scale was ranged from 0.64 to 1.00 (Figure 2). Mean technical efficiency for tomato was 0.83 which means that tomato farmers could reduce their input use by 17% when output held constant. Most of the Farms (50) were operating their farm below frontier while only few tomato farms (10) were operating on the frontier.

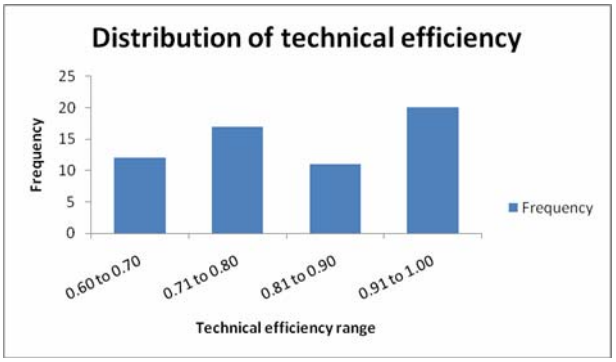

Figure 2. Technical efficiency of tomato farmers

Technical efficiency measurements of different vegetables in different countries were showing the variation of efficiency among different countries (Table 4). Technical efficiency of tomato in India, Pakistan, Ghana and Nigeria was 0.86, 0.74, 0.71 and 0.87 respectively. In the present study, mean technical efficiency of tomato in Bangladesh was 0.83 which is consistent with other previous studies (Figure 2). India is one of the largest tomato producers in the world and Bangladesh can adopt the production technology for improving their efficiency. Baree (2012) found the similar technical efficiency score for onion in Bangladesh. Efficiency of vegetable farmers in Tanzania, Cameroon and Srilanka are 0.67, 0.67 and 0.52 respectively which was quite lower than that of Bangladesh (Table 4).

Factors affecting efficiency of tomato farmers

Technical efficiency of tomato farmers were influenced by different factors such as age, education, experience, training, extension service, family size and high yielding variety adoption (Table 5). Education, high yielding variety adoption and training were significant at 1% while age was significant at 5%. Positive coefficient of

education means the higher the years of schooling, the higher the incidence of efficiency. Education is not only escalating agricultural productivity by increasing their understanding of modern farming techniques but also opening the mind of farmers (Schreinemachers *et al*., 2016). Murthy *et al*. (2009) found that Educational level had positively significant effect on technical efficiency of tomato farmers. In addition, training program was positively related with farmers' efficiency which implies farmers who had received training were significantly more efficient compared to training non-receiver. Generally, training program facilitate to practice modern farming techniques that assist to enhance productivity, efficiency and income of farmers (Schreinemachers *et al*., 2016).

Table 4. Technical efficiency of vegetable farmers in different countries

Sl. No	Author name	Year	Country	Vegetables	Mean Technical efficiency
1	Murthy *et al*.	2009	India	Tomato	0.86
2	Baree	2012	Bangladesh	Onion	0.83
3	Rajendran *et al*.	2015	Tanzania	Vegetable	0.67
4	Akamina *et al*.	2017	Cameroon	Vegetable	0.67
5	Karunarathna	2014	Srilanka	Vegetable	0.52
6	Shettima	2015	Nigeria	Onion	0.81
7	Shettima	2015	Nigeria	Tomato	0.87
8	Khan and Gafar	2013	Pakistan	Tomato	0.92
9	Donkoh	2013	Ghana	Tomato	0.71
10	Ogunniyi and Oladejo	2011	Nigeria	Tomato	0.54
11	Mari & Lohano	2008	Pakistan	Chilli	0.83
12	Mari & Lohano	2008	Pakistan	Tomato	0.74
13	Mari & Lohano	2008	Pakistan	Onion	0.59

Table 5. Tobit regression for factors affecting tomato farmers' efficiency

Adoption	Coefficient	Standard error	P-value
Constant	0.068	0.104	0.000
Age	-0.002**	0.001	0.022
Education	0.022***	0.005	0.000
Family size	0.003	0.008	0.682
Experience	-0.001	0.005	0.799
Training	0.068***	0.027	0.014
Variety adoption	0.074***	0.022	0.001
Extension service	-0.015	0.026	0.546
Lr chi^2		80.52	
Prob>chi^2		0.000	

(Significance level: *** for 1%, ** for 5% and * for 10%)

Negative but significant coefficient of age implies that efficiency reduces with the increases of age. The probable reason of this result was that aged farmers were not interested to adopt new farming techniques that influence the efficiency of farmers (Albert & Duffy, 2012; Tauer & Lordkipanidze, 2000). Murthy *et al*. (2009) found that younger tomato farmers were more efficient than older farmer. In addition, adoption of high yielding local variety had found positive relation with farmers' efficiency. It indicates that high yielding local variety user farmers were more efficient than exotic high yielding variety user. Ali *et al*. (2014) found that earlier flowering; better growth performance, less virus infection and less harvest time of high yielding local varieties can save the production cost and management. Other factors like experience, family size and extension service were insignificant. Alam (2011) and Coelli *et al*. (2002) also found the insignificant relation between experience and efficiency.

Conclusion and policy implications

This study tried to estimate the efficiency level and factors affecting efficiency of tomato producer in Mymensingh district of Bangladesh. Result found that tomato farmers were not entirely efficient. Their average efficiency score was 0.83 implies that farmers could reduce their input use by 17%. Since farmers were operating under the frontier, there is a vast room for efficiency improvement. Moreover, lack of training and education exacerbates the inefficiency. Training, education and local high yielding variety adoption have positive and significant effect on farmers' efficiency while age of tomato farmers has negative effect on efficiency. This study will help the tomato producers to facilitate the optimal input use that assist them to reduce the input cost and increase productivity of tomato. It also shows the significance of different socio-economic characteristics such as training, education, age and high yielding local variety adoption.

As inputs were used inefficiently, farmers have to follow proper input management practices. Training and extension facility is not sufficient as needed in Bangladesh. Therefore, government needs to ensure quality training and extension facility for vegetable farmers. Extension agents and training personnel can encourage the vegetable farmers to adopt new technology that assist them to increase productivity and efficiency. Most of the cases, aged farmers shows risk averse attitude for receiving new technology but more extension facility / service can change their attitude towards risk. Farmers should be encouraged to use local high yielding variety instead of exotic high yielding variety.

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