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Determinants of Efficiency and Inefficiency factors: An Analysis of Potato Farming in Bangladesh

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Abstract: Bangladesh government encourages farmers to produce more potato (rabi crop) for reducing pressure on rice consumption, reducing potato import costs and increasing potato export for foreign currency. It requires more efficient use of farmers' resources. This study focuses on determination the efficiency and inefficiency factors of potato farming in Bangladesh. This may help farmers decide whether to improve efficiency without introducing new technologies or increasing resources. The Cobb-Douglas Stochastic Frontier Analysis is used to estimate four districts' technical, allocative, and economic efficiencies of potato farming. From the analysis, all input factors (land, labor, tilling, seed, fertilizer, irrigation pesticide, and vitamin) positively and significantly affect potato production. The source of inefficiency parameter (0.853) is statistically significant, implying that socio-economic and infrastructure factors determine the inefficiency of potato production. Except for family size, land fragmentation, de-weeding, access to credit, cold storage, education, training, experience, and age contribute significantly to TE, AE, and EE in potato farming. To operate at a full efficiency scale, a farm can improve 36 percent economic efficiency, 25 percent allocative efficiency and 14 percent technical efficiency without changing or improving cultivation technologies. This study finds that farms are more technically efficient among three efficiencies and farms need to pay more attention to improve economic and allocative efficiencies. Further research could examine whether efficiency factors explain differences in efficiency and how farmers can adapt to new programs related to training and education.

Keywords: Stochastic Frontier Analysis (SFA), Economic Efficiency (EE), Allocative Efficiency (AE), Technical Efficiency (TE), Potato Farming

Introduction

Now-a-days developing countries are paying more attention to improving efficiency of agricultural production. The estimation of efficiency has been an area of interest for economists because it measures the performance and success of a farm. Through efficiency and inefficiency estimations, farmers can decide to improve productivity whether they need to develop new technologies or use more resources. The agricultural

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sectors' farming efficiency is considered an essential factor if the agricultural output needs to grow sufficiently rapidly to meet growing populations' demand for raw materials and food. Potatoes are now considered as a cash crop and their importance has increased in the domestic and international markets. The Potato sector is now a growing Government policy concern.

Reardon et al., (2012) has found a "Quiet Revolution" of potato production in Bangladesh. In considering consumption, harvested area and production, potatoes' rank is just after rice and wheat. In Asia rank of Bangladesh potato is 3rd as production volume (MT), 4th as the production area (ha), 3rd as consumption (kg/capita/year) and 4th as production yield (tones/ha). Rank position Bangladesh is increasing in world potato production. It was ranked 9th in 2005, secured 8th position in 2012, and 7th in 2014 (FAO, 2014). Farmers cultivate local and High Yielding Varieties of Potatoes in Bangladesh. So far, scientists have invented 61 types of potato varieties. Farmers are interested in cultivating more potatoes because of their high yielding and profit-making than other crops(Hossain et al., 2014). Potato is both a food and a cash crop.

Literature Review

This study has reviewed research work on efficiency of potato sector for both Bangladesh and some other countries. Most of the study focused on estimating technical efficiency using Stochastic Frontier Analysis. However, there is a little information on efficiency, especially technical, allocative, and economic efficiency of potato sector in Bangladesh. Shahriar et al., (2013), Siddique et al., (2015), Amir Hamjah, (2014), and Hossain et al., (2008) examined the technical efficiency of potato cultivation using Cobb-Douglas stochastic frontier production function. Begum & Alam (2010) examine the economic efficiency of potato farmers using Translog Stochastic Cost Frontier. From the other countries, Maganga (2012), Alam et al. (2012), Nyagaka et al. (2010), Abedullah & Ahmad, (2006), Amarasinghe & Weerahewa (2001), Wilson et al. (1998) used stochastic production frontier model to assess technical efficiency in resource use and identified the underlying determinants of variation in production efficiency of potato producers. Most of the researchers does not examine three types of efficiency (economic, allocative, and technical) of potato farming in Bangladesh at the same study.

All the researchers considered human labour/rent/hired labour, potato cultivated area/land rent, diesel and machinery rent/mechanical power, purchased seeds, fertilizer and agrochemicals cost, weedicides cost, pesticide cost, irrigation water cost as input variables for production function. Whereas farm specific efficiency factors such as Age, household size, credit access, operated land, non-farm employment, farming experience, level of education, family size, extension linkage, training, degree of specialization, irrigation system, distance from the main channel (head and tail), distance from the village to city, membership in a farmers' association, quality of seed are considered.
The present study explores the efficiency level and identifies factors affecting efficiency of potato farming to develop policy parameters to improve the existing situation in Bangladesh.

Methodology

Sampling and data

Potato is cultivated in almost all the districts of Bangladesh in winter. This study uses a semi-structured questionnaire to randomly collect 300 data from purposively selected four highest potato grown districts: Munshigonj, Rangpur, Dinajpur, and Joypurhat.

Table 1: Number of respondents from sampling area

Districts	Upazila	Farmers
Munshigonj	Tongibari	50 farmers
	Sirajdikhan	50 farmers
Rangpur	Pirgonj	50farmers
Dinajpur	Hakimpur	50 farmers
Joypurhat	Panch Bibi	50 farmers
	Kalai	50 farmers
4 Districts	6 Upazilas	300 Farms

Table 2: Following Primary Data were Collected from the Survey

Variables	Required Information	Units
Output	Current year total potato production	('000) Kg.
Land	Total land of potato cultivation	('000) Decimal
Labor	Total labor cost	('000) Tk.
Tilling	Total tilling cost	(‘000) Tk.
Seed	Quantity of used seed	('000) Kg.
Fertilizer	Total fertilizer cost	('000) Tk.
Irrigation	Total cost of irrigation	('000) Tk.
Pesticides	Total pesticide cost	('000) Tk.
Vitamin	Total cost of vitamin applied	('000) Tk.
Factors Associated with inefficiency	Age of farmers	Year
	Education of farmers	Year
	Training	Dummy (Yes = 1, No = 0)
	Experience of potato cultivation	Year
	Land fragmentation	Average plot size
	Access to credit	Dummy (Yes = 1, No = 0)
	Cold storage facility	Dummy (Yes = 1, No = 0)
	Household size	Number of family member
	Weed uprooting cost	Tk.

Estimation Method

Farrell (1957) pioneering paper on the measurement of efficiency led to develop several approaches to efficiency analysis (Figure 1). Among these, stochastic Frontier Analysis is generally used to assess the performance of the agricultural sector. This study uses Stochastic Frontier Analysis (SFA) of the parametric approach.

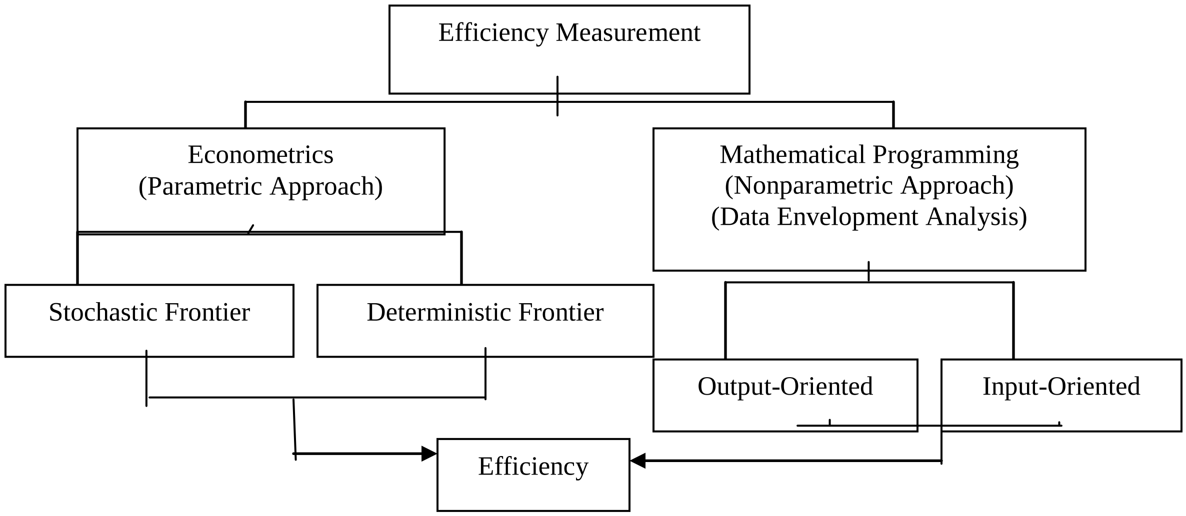

Figure 1: Approaches to Efficiency Measurement (Wadud, 1999)

Stochastic Frontier Analysis

The stochastic frontier analysis is a parametric econometric approach which has independently proposed by Aigner et al., (1977) and Meeusen et al., (1977).

The stochastic frontier production function involves an error term that had two components: one to account for random effects (luck, weather, measurement error in the output variable, etc.) and another to account technical inefficiency. SFA approach is closer to the theoretical production function that gives a maximum output from a given input mix and is more realistic than the deterministic frontiers of Farrell (1957), D. J. Aigner & Chu (1968), and Wadud, (1999). This study applies a Cobb-Douglas stochastic frontier Analysis Method. It is self-dual, and its dual cost frontier model forms the basis for computing technical, allocative, and economic efficiencies.

This study considers total potato production in the current year as dependent variable, land, labor, tilling, seed, fertilizer, pesticide, vitamin as independent variables and age of farmers; education of farmers; training; experience of potato cultivation; the number of plots; access to credit; cold storage facilities; household size; de-weeding or weed uprooting cost as inefficiency factors.

Empirical result

Table 3: Maximum Likelihood Estimates

Name of the variables	Parameters	Coefficients	t - ratios
Constant	β_0	2.799	2.432*
Ln of Land	β_1	0.575	13.786*
Ln of Labor cost	β_2	0.337	6.509*
Ln of Tilling cost	β_3	0.404	2.829*
Ln of Seed	β_4	0.491	3.832*

Ln of Fertilizer cost	β_5	0.285	4.296*
Ln of Irrigation cost	β_6	0.152	2.799*
Ln of Pesticide cost	β_7	0.126	7.726*
Ln of Vitamin cost	β_8	0.068	7.972*
Inefficiency Variables			
Constant	δ_0	4.792	2.864*
Age	δ_1	-0.524	-8.875*
Education	δ_2	-0.377	-3.997*
Experience	δ_3	-0.256	-3.523*
Land Fragmentation	δ_4	0.338	3.154*
Family size	δ_5	0.097	0.333
De-weeding	δ_6	-0.297	-3.875*
Access to credit – dummy	δ_7	-0.383	-9.356*
Cold storage – dummy	δ_8	-0.212	-6.376*
Training – dummy	δ_9	-0.432	-3.694*
Variance Parameters			
$\sigma^2 = \sigma_v^2 + \sigma_u^2$		0.064	2.404*
$\gamma = \left(\sigma_u^2 / \sigma^2 \right)$		0.853	13.781*
σ_v^2		0.009	
σ_u^2		0.055	
Log likelihood Value		324.670	

*At 5% level of significance Source: Authors' estimation

The empirical result from the above table shows that the coefficients of all factors of production are statistically significant and have positive signs. Which implies that all inputs are potential factors for the capability of farms to utilize the existing infrastructure and technology adequately for potato production. Sum of all coefficients of potato production factors ($\sum_{i=1}^{8} \beta_i$) is 2.44, implying increasing returns to scale in potato production.

The Land elasticity (0.575) indicates that farmers are not cultivating total land for potato production. Land directly affects agricultural production as land is the main factor for potato production, but marginal productivity decreases due to the complementary relationship between land and other inputs.

The elasticity of labor is 0.337, so that 1% increase in labor as an input will increase 33.7% potato output. Labor productivity and efficiency depend on experience, education and training, and age. The elasticity of tilling and seed are 0.404 and 0.491, respectively. The land should be ploughed well by cows or tractors after the acquisition of land. Seeds (local or HYV varieties) should be good quality since it is a prerequisite for good production. This suggestion has similarities to Shahriar et al., (2013).

The elasticity of fertilizer (0.285) indicates that farmers should use good quality fertilizer for increasing productivity of local or HYV varieties. The elasticity of irrigation, pesticide, and vitamins are 0.152, 0.126, and 0.068, respectively reflecting that they have relatively small effect.

The inefficiency factors are statistically significant indicating that they have significant contribution in explaining the technical inefficiency effects in potato production.

The estimated value of γ (0.06) and σ^2 (0.85) are statistically significant which indicates sample farms have inefficiency effects in potato farming. The estimated value of the random component σ_u^2 (0.055) have significant contribution to technical inefficiency of potato production in determining variability and the level of output of potato cultivation.

The negative education coefficient indicates that the farmers are more technically efficient when they have higher years of schooling. Age and experience coefficients are negative, implying that as farmers get older, their knowledge, experiences, and intuition increase, and they become more technically sound. The higher the farmers are more educated they can easily adopt new technology. The more highly educated they are, the more they tend to adopt new technology, etc.

Cold storage facilities allow potato farmers to keep their potato for a good margin of their potato selling. If the farmers have access to credit and training, the inefficiency of production performance can be reduced substantially. De-weed also helps potato production to be efficient. Less fragmented land is more technically efficient since tilling and irrigation have become easy. However, the family size coefficient is positive but not significant.

Estimation of Production, Cost, and Input Demand Functions

To obtain the inefficiency component need to derive the dual cost frontier using stochastic production frontier. The stochastic production function for potatoes is constructed from table 3 to find the frontier cost function as follows.

I. Stochastic Production Function is as follows:

$$y_i = 2.799\ x_{i1}^{0.575}\ x_{i2}^{0.337}\ x_{i3}^{0.404}\ x_{i4}^{0.491}\ x_{i5}^{0.285}\ x_{i6}^{0.152}\ x_{i7}^{0.126}\ x_{i8}^{0.068}$$

(Where, number of farms: i = 1, 2, 3, …, 300)

II. Dual stochastic frontier cost function:

$$C\ (P_{ik}, \tilde{y}_i) = 4.435\ P_{i1}^{0.236}\ P_{i2}^{0.138}\ P_{i3}^{0.166}\ P_{i4}^{0.201}\ P_{i5}^{0.117}\ P_{i6}^{0.062}\ P_{i7}^{0.052}\ P_{i8}^{0.028}\ \tilde{y}_i^{0.410}$$

(Where, number of farms: i = 1, 2, 3, …, 300)

III. Input demand function is

$$x_{i1} = \frac{\partial C}{\partial P_{i1}} = 4.435(0.236)P_{i1}^{(0.236\ -\ 1)}\ P_{i2}^{0.138}\ P_{i3}^{0.166}\ P_{i4}^{0.201}\ P_{i5}^{0.117}\ P_{i6}^{0.062}\ P_{i7}^{0.052}\ P_{i8}^{0.028}\ \tilde{y}_i^{0.410}$$

or,

$$x_{i1} = \frac{1.05\ P_{i2}^{0.138}\ P_{i3}^{0.166}\ P_{i4}^{0.201}\ P_{i5}^{0.117}\ P_{i6}^{0.062}\ P_{i7}^{0.052}\ P_{i8}^{0.028}\ \tilde{y}^{0.410}}{P_{i1}^{0.764}}$$

(Where, number of farms: i = 1, 2, 3, …, 300)

This study examines the economic, technical, and allocative efficiencies from these dual-cost functions.

The following tables present the frequency distribution (%) of farms' economic, technical, allocative efficiencies scores.

Table 4: Frequency Distribution (%) of Farms Specific Efficiencies

Efficiency Index (%)	TE	AE	EE
1-40	0	1	3
40-50	2	4	16
50-60	3	10	18
60-70	6	17	27
70-80	12	28	28
80-90	35	24	7
90-100	42	16	1
Total Farms	300	300	300
Mean	86	75	64
Minimum	42	38	36
Maximum	100	100	95
Standard Deviation	12	14	12

Source: Authors' estimation

Table 4 shows the frequency distribution (%) of farm-specific efficiencies. From the table, 23% of farms are technically efficient and fall 1-80% efficiency range and 77% of farms are between 80-100% efficiency range. For allocative efficiency (AE), 60% of farms fall in the 1-80% efficiency range, and the rest 40% of farms are included in 80-100% AE range. In that instance, economic efficiency (EE), 92% of farms fall in 1-80% efficiency range, and 8% of farms are highly economically efficient (80-100%) range. From the above results, it is seen that efficiency of farms varies significantly and economic inefficiency is comparatively lower. Therefore, there is a scope of efficiency improvement.

The estimated parameters of the stochastic frontier model are all positive, as expected. To operate at a full efficiency scale, Potato farmers can improve their production by14% technical efficiency (TE), 25% allocative efficiency(AE), and 36% economic efficiency (EE) without changing or improving cultivation technologies. Technical efficiency is similar with Shahriar, et al (2013). There is an opportunity to increase potato production through improving farming efficiency. Farms get an optimal level of production when TE = 1 without changing quantity of inputs.

Inefficiency Factors

The factors affecting economic, allocative, and allocative efficiencies are shown in Table 5.

Table 5: Inefficiency factors in potato farming

Factors	Technical Inefficiency		Allocative Inefficiency		Economic Inefficiency	
	Coefficients	t – ratios	Coefficients	t – ratios	Coefficients	t – ratios
Constant	1.792	2.864*	0.752	8.927*	0.630	17.214*
Age	-0.524	-8.865*	-0.048	-5.412*	-0.010	-13.115*
Education	-0.377	-3.997*	-0.031	-3.585*	-0.018	-10.902*

Experience	-0.256	-3.523*	-0.038	-3.351*	-0.010	-10.581*
Land Fragmentation	0.337	3.155*	0.015	7.171*	0.031	18.063*
Family size	0.097	0.333	0.009	0.232	0.006	0.751
De-weeding	-0.596	-3.875*	-0.004	-3.344*	-0.002	-8.470*
Access to credit - dummy	-0.982	-9.356*	-0.019	-2.263*	-0.024	-15.285*
Cold storage – dummy	-0.012	-6.376*	-0.015	-6.006*	-0.017	-7.575*
Training – dummy	-1.43	-3.694*	-0.021	-10.238*	-0.063	-3.594*

*At 5% level of significance. Source: Authors' estimation

Table 5 shows factors affecting all three (TI, AI, EI) inefficiency in farming. Coefficients of all factors are negative and statistically significant effects on economic, technical, and allocative inefficiencies. It implies an increase in Age. Education, Experience, De-weeding, credit (loan) availability, Training and Cold Storage will decrease inefficiency. While Land Fragmentation parameter is positive with significant at 5% level, that means Land Fragmentation increases inefficiency. The contribution of inefficiency factors affect to technical inefficiency is highest compared to Allocative and Economic Inefficiencies.

Implication and Conclusion

Farmers efficiency of potato farming depends on fragmentation of land, use of quality seeds, modern technology, fertilizer, and other inputs and farmers' education and experience. The positive signs of estimated Cobb-Douglas stochastic frontier's coefficients indicate that to determine potato production these inputs have important contributions. In potato production farm households have increasing returns to scale. The estimated γ and σ^2 are statistically significant which indicates sample farms have inefficiency effects in potato farming. The random component σ_u^2 has a significant contribution to the technical inefficiency of potato production in determining the variability and production level of potato crop in Bangladesh. It is seen from the results of inefficiency effects model that the random effect is the dominate factor in composed error term. The estimated δ-coefficients indicate that variables of inefficiency model have significant contribution in explaining technical inefficiency in potato farming. Findings imply there is significant economic, allocative, and technical inefficiencies in potato farming. Efficiency can improve through improving farm income, farm household welfare, and increasing the level of production.

The infrastructure and socio-economic factors jointly determine the variability in potato production. Farms cannot control random errors in the agriculture sector. Therefore, it may conclude that Stochastic Frontier Analysis is suitable for measuring inefficiency of potato farming. This study emphasizes that agriculture related education and training are important factors for improving the farms' ability to receive and understand information about modern technology to cultivate potatoes in an efficient and cost minimizing way.

It concludes that in achieving production efficiency in potato farming need to pay more attention to extension programs, access to credit facilities, better utilization of fertilizer, land preparation methods, irrigation, land management policies and tenure. These efficiency factors must also be examined to see whether efficiency factors explain differences in efficiency and how farmers can adapt to new programs related to training and education.

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