Research Article

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Assessing the impact of fertilizer subsidy on farming efficiency: A case of Bangladeshi farmers

Abstract: The study has been conducted to assess the micro level impact of fertilizer subsidy on farming efficiency given the heterogeneous farm structures and universal subsidy policy in Bangladesh. The research utilizes primary data, which were collected through personal interview of 300 farm households located in three districts from northern part of Bangladesh. Multistage purposive sampling was followed for selecting the sampling units based on concentration of rice farming. Data Envelopment Analysis (DEA) reveals that the farms are inefficient in combining inputs in a cost minimizing way, although they are technically more efficient. Results from Tobit models for different farm size groups prove that fertilizer subsidy has significant impact on improving farming efficiencies for marginal and small farms in study areas while leaving insignificant impact for medium and large farms. Further increases in fertilizer subsidy will bring significant productivity increases for these smallholder farmers. Therefore, policy interventions should favor these farms for acceleration of agricultural growth.

Keywords: Universal subsidy policy, economic efficiency, farm size group, data envelopment analysis.

1 Introduction

Improvements on agricultural production through improving the farming efficiency are the end results expected from input subsidy program. Providing fertilizer subsidies to farmers through a reduced market price ensures the fertilizer availability, which subsequently is expected to influence farm level efficiency and production. FAO (2015) estimates that global food production must increase by 70 percent by 2050 to feed an additional 2.3 billion people. Eighty percent of the increase in production in developing countries will have to come from improved crop yields and production (Pullabhotla and Ganesh-Kumar 2012). Tandon and Narayan (1990) considered the chemical fertilizers as the main fuel for the high yielding rice varieties that ignited the Green Revolution to understand the role of fertilizer for increasing production. Fertilizers support half of the world's grain production with an estimated 162 million tons of fertilizer nutrients applied to farms worldwide annually (Shah et al. 2008; Pullabhotla and Ganesh-Kumar 2012). This is also true for Bangladesh agriculture, because the country has virtually no possibility of increasing its cultivable land area, but must increase crop yield and production for an increasing population. Following the introduction, the use of chemical fertilizers in Bangladesh agriculture grew from 8.8 kg of nutrients per hectare in 1968 to 208.66 kg per hectare of land in 2013-14 (World Bank 2016, http://data.worldbank.org/indicator/AG.CON.FERT.ZS). Currently, more than 97 percent of all farm households are using chemical fertilizers (BBS 2017). Subsidies have traditionally played an important part in the pricing of fertilizer in the country. Fertilizer subsidies were initiated with an overall objective of augmenting farmers' optimum usage of fertilizers technically and boosting agricultural production. Recent years have seen a growing interest in large scale fertilizer subsidies in agricultural development. The expenditure on fertilizer subsidy rose rapidly over the years and the total amount has been amplified more than threefold from BDT 35.34 billion in 2007-08 to BDT 119 billion in 2013-14 (MoFDM 2015). This acts as an incentive to boost production by reducing costs and at the same time represents the largest element of public expenditure in agriculture. Because fertilizer makes such an important contribution to high crop yields, its availability and use, quality, price and subsidies are all important to policy makers and to the researchers alike. Despite achievements in terms of increasing fertilizer usage and boosting agricultural production, fertilizer subsidies can

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be considered to be an inefficient allocation of public investments in the present context of Bangladesh, where agriculture is characterized by small farms, which have greatly contributed to increasing food self-sufficiency over the last 30 years (World Bank 2014). Alam (2013 presented at the International Conference 'Agricultural Transformation in Asia: Policy Options for Food and Nutrition Security', Siem Reap, Cambodia, 25-27 September 2013) stated that universal subsidies given for fertilizers are distorting prices among different farm size groups and draining out scarce government fiscal resources. As the land distribution is highly uneven in the country, which farm groups are benefitting more out of this subsidy is the major issue of concern in the present context. Moreover, the extent to which fertilizer subsidy has influenced farm production depends on the improvements in farming efficiency. Therefore, the contribution of current fertilizer subsidy policy on improving farm level efficiency has yet to be analyzed in the country context.

Differential experiences on the impact of fertilizer subsidy on farm efficiency have been found in different countries. While some evidences support for positive influences, some others do not support such kind of findings. For example, Fan et al. (2007), Dorward et al. (2004) and Smith and Urey (2002) explored that, although farm production increased in the initial phase of fertilizer subsidy policy in India, such effects were difficult to observe afterwards. On the contrary, Sharma and Thaker (2009) concluded in another study that fertilizer subsidy in India was more equitably distributed among farm groups and a reduction is likely to have an adverse impact on farm production of small and marginal farmers, as they do not benefit from higher output prices, yet benefit from lower input prices. Fertilizer subsidy, after introduction in 2005, has reduced input costs and subsequently, has positively influenced efficiency of paddy production in Sri Lanka (Wickramasinghe et al. 2009, Fertilizer policy on paddy farming: Evaluation of subsidy program 2005, unpublished report, Semasinghe 2014). Darko and Ricker-Gilbert (2013) employed stochastic frontier analysis to investigate efficiency among farmers and how it is affected by input subsidy programs. They reveal that fertilizer subsidy improves efficiency among maize farmers in Malawi. Sek (2015) provides empirical evidence that the fertilizer subsidy program has indeed significantly contributed to improve farmers' efficiency in Senegal, all else being equal. His results tend to validate the argument that lower fertilizer prices, as a result of subsidy, provide incentives for farmers to use more of the inputs, which subsequently translates into increased output.

This brief review reveals that such type of analysis is scant in Bangladesh, where farm production is vulnerable to input prices and costs. As such, input uses and efficiencies vary among different farm size groups. To what extent fertilizer subsidy has influenced the efficiency of farms, is a question of analysis at the present context of the country where fertilizer subsidy represents a considerable part of government expenditure. At the same time, measurement of farm-level efficiency in production is not new in the country. But most of the studies consider only technical efficiency (Bäckman et al. 2011; Khan et al. 2010; Asadullah and Rahman 2009; Rahman and Rahman 2009; etc.) while some others also consider allocative and economic efficiencies (Islam et al. 2011; Coelli et al. 2002; Wadud 2003). No studies have been found in literature to deal with the micro level impact of fertilizer subsidy under universal subsidy policy setup on farming efficiency in Bangladesh. To assess the effectiveness of fertilizer subsidy in raising farm production, the improvements in farming efficiency must be measured first. This will assist policy makers in identifying ways for refining subsidy policies in order to improve production performances of different farm groups. Therefore, this research contributes to literature by being the first to find out such impact of fertilizer subsidy. To this backdrop, this research aims to empirically reveal the extent to which the fertilizer subsidy program has been effective in terms of boosting farming efficiency.

2 Research methodology and empirical model

The research is conducted at farm household level, which is considered as the sampling unit. Based on the objectives and nature of the research, sampling units were identified through a multi-stage sampling strategy based on purposive selection. At first stage, three (Rangpur, Mymensingh and Dhaka) out of eight divisions of the country were selected based on rice production intensity. At the second stage, three districts, namely Dinajpur, Mymensingh and Tangail, from each division respectively were chosen which had the recorded fertilizer consumption. From each district, several sub-districts were considered purposively after consultation with key informants from Department of Agricultural Extension (DAE) and Bangladesh Rice Research Institute (BRRI). Finally, with the help of Agricultural Extension Officer (AEO) and Sub-Assistant Agricultural Officers (SAAO) in each sub-district, a total of 300 farm households belonging to different farm size

groups (marginal, small, medium & large[1]) were selected. Among the sampled farm households, 14.33 percent were marginal farms, 52.00 percent were small farms, 28.33 were medium farms and 5.33 percent were large farms, respectively. This sample distribution is representative of overall Bangladesh agriculture, where 84.39 percent of total farm households (more than 15 million) are marginal and small, 14.04 percent are medium and 1.54 percent are large farmers (BBS 2017). Primary data were gathered through the field survey method following a structured interview schedule. To assess the validity and to check for necessary improvements, the interview schedules were pre-tested by the researcher in one of the sample study areas. Moreover, some qualitative information was also obtained through focus group discussions (FGDs) and key informant interviews (KIIs) to get general ideas about fertilizer subsidy policy and prices. The data and information collected were organized and analyzed for their meaningful interpretation in line with achieving the objectives.

The empirical approach considered in this research consists of two parts. At first, a non-parametric approach was employed to compute farming efficiency scores for individual farms. Following Farrell (1957) and others, farming efficiency is a combination of three types of efficiencies: technical, allocative and economic efficiencies. Technical efficiency (TE) relates to the farm's ability to achieve highest possible output from a given level of input or obtaining a given level of output using minimum feasible amounts of inputs (Varian 1992). Allocative efficiency (AE) is the ability of a farm to make optimal decisions regarding resource allocation (Fan 1999). A combination of technical and allocative efficiencies results in a measure of economic efficiency (EE). According to Shuwu (2006), economic efficiency assumes that the farmer has made right decisions to minimize costs and maximize profits, which means he or she is operating on the profit frontier. Efficiency can be estimated by employing either parametric or non-parametric methods. However, it has been argued that the parametric approach may not be appropriate when farmers face different factor endowments (Ali and Flinn 1989) as in this research where not all farms have same factor ownership. One of the non-parametric approaches for estimating farming efficiency is known as the data envelopment analysis (DEA), which does not impose any prior parametric restrictions on the production technology

as compared to parametric approach and hence, less sensitive to model misspecification (Cooper et al. 2007; Coelli 1995). DEA is based on linear programming technique and does not require any bindings on sample sizes. The efficiency scores vary from zero (a zero output from non-zero inputs) to one (the most efficient farms located at the frontier). Following Banker et al. (1984), the input based technical efficiency (TE) under variable returns to scale (VRS) is obtained by solving the following problem:

$$TE_i = Min_{\theta\lambda}\theta,$$ (1)
$$\text{Subject to} - y_i + Y\lambda \geq 0$$
$$\theta x_i - X\lambda \geq 0$$
$$N_1 \lambda = 1$$
$$\lambda \geq 0$$

Where, θ is a scalar; y_i is a vector (m×1) of rice output of the ith farm; x_i is a vector of (k×1) of inputs of the ith farm; Y is the rice output matrix (n×m) for n farms; X is the rice input matrix (n×k) for the n farms; N_1 is an N×1 vector of ones; and λ is an N×1 vector of constants. The value of θ is the technical efficiency score for i^{th} farm. It will satisfy: $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence, a technically efficient farm. The linear programming (LP) problem is solved N times to obtain a value of θ for each farm in the sample. The economic efficiency score for a given farm is obtained by first solving the following cost minimizing LP model:

$$p_i x_i^*,$$ (2)
$$\text{Subject to} - y_i + Y\lambda \geq 0$$
$$x_i^* - X\lambda \geq 0$$
$$N_1 \lambda = 1$$
$$\lambda \geq 0$$

Where, p_i is a vector of input prices for i^{th} farm and x_i^* (calculated by the model) is the cost minimizing vector of input quantities for i^{th} farm, given the input prices p_i and the output levels y_i. All other variables in equation (2) are same as previously defined. Therefore, economic efficiency (EE) of ith farm is calculated as:

$$EE_i = p_i x_i^* / p_i x_i$$ (3)

That is, EE is the ratio of minimum cost to observed cost for the ith farm. Following Farrell (1957), the allocative efficiency (AE) is then calculated using the following relationship:

$$AE_i = EE_i / TE_i$$ (4)

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1 Marginal farmers operate between 0.02 and 0.2 ha of land; small farmers operate between 0.2 and 1.0 ha of land; medium farmers operate between 1.0 and 3.0 ha of land and large farmers operate above 3.0 ha of land (DAE, 1999).

Where, EE_i = the economic efficiency calculated for farm i using equation (3) and TE_i = the technical efficiency calculated for farm i using equation (1). As with TE_i, the value for EE_i and AE_i will be ≤ 1, with a value of 1 meaning the farm is economically or allocatively efficient and less than 1 meaning the farm is economically or allocatively inefficient, respectively.

Measuring efficiency allows for the testing of hypotheses regarding to the sources of efficiency differentials among farms (Farrell 1957). After estimating farm size wise efficiency scores, economic inefficiency scores were simply calculated by subtracting the efficiency scores of each farm from 1 as the value of one implies the most efficient farms at the frontier. These economic inefficiency scores were then regressed on a set of explanatory variables along with the 'amount of fertilizer subsidy' variable in a Tobit regression model to see how the dependent variable is influenced by these factors. The Tobit model is the most appropriate in this particular case since the dependent variable, the calculated economic inefficiency scores from the DEA analysis, is censored at 0. Let we assume the following regression equation:

$$IE_i = \beta_i X_i + \omega_i \tag{5}$$

Where, β_i denotes a (n×1) vector of unknown parameters, X_i is a (n×1) vector of explanatory variables and ω_i is a (n×1) vector of residuals that are independently and normally distributed with mean zero and variance σ_ω^2. As the value of inefficiency is zero for some farms, applying OLS to above equation 5 will result in biased and inconsistent estimates. Instead, a censored regression model developed by Tobin (1958) can be specified as follows:

$$IE_i = \beta_0 + \beta_{1i} X_{1i} + \beta_{2i} X_{2i} + ... + \beta_{ni} X_{ni} + \omega_i \quad \text{if } IE_i^* > 0, \text{ that is,}$$
inefficiency is not zero; and $IE_i = 0$ otherwise, that is, inefficiency is zero (6)

Following Maddala (1992), the log likelihood function for the Tobit model can be written as:

$$\log L = \sum_0 \log (1-\phi) + \sum_1 \log (1/\sqrt{2\pi} \sigma_\omega^2) - \sum_1 (1/2\sigma_\omega^2) (IE_i - \beta_i X_i)^2 \tag{7}$$

Using the maximum likelihood estimation, the Tobit model was estimated for three farm size groups separately. Based on available literature and insights gained from field survey, seven explanatory variables are considered for Tobit regression model. These are, farming experience (years), years of schooling, no. of working member, share of off-farm income, amount of fertilizer subsidy received by farmers (BDT/ha) and two dummy variables namely, soil fertility assessment (1=good/average and 0=otherwise) and extension services (1=received and 0=otherwise).

The amount of fertilizer subsidy (BDT/ha) enjoyed by a farm can be endogenous in the Tobit model to determine the impact of fertilizer subsidy on farm inefficiency. In one hand, the amount of subsidy variable is derived from the farm's fertilizer usage data which directly affects, in turn, the farm efficiency. Efficient farmers can use more fertilizer leading to more subsidies. On the other hand, farm's fertilizer usage is influenced by the subsidy amount itself causing simultaneity problem between the dependent variable 'farming inefficiency' and the independent variable 'amount of fertilizer subsidy'. In view of this, endogeneity of 'amount of fertilizer subsidy' is tested using the Durbin-Wu-Hausman (Davidson and Mackinnon 1993; Cramon-Taubadel and Salidas 2014) test. To accomplish this, two stage least square (2SLS) estimation technique including instrumental variable (IV) is followed. At first stage, a regression for the variable 'amount of fertilizer subsidy' on the instrumental variables and the other independent variables in the original inefficiency model is run. For this purpose, two instrumental variables were introduced here, one is the dummy for credit access and another one is the dummy for having fertilizer purchasing capability in season. The instruments should satisfy two major properties which are (i) instruments should not be correlated to ω_i but (ii) correlated with the endogenous variable (Wooldridge 2002; Baum et al. 2003; Bascle 2008). Hence, instruments are variables, which are directly related to the endogenous variable (amount of subsidy received) and may not have a direct influence on the dependent variable (farming inefficiency). In the present research, both the instruments influence the quantity of fertilizer that a farm uses in production and hence, the amount of subsidy. Under the null hypothesis of no endogeneity, if it is rejected, the Tobit model will be re-estimated at the second stage replacing the endogenous variable with the fitted values from the first regression. Otherwise, the original model will be estimated. Following Wooldridge (2010), the simultaneous equation for 'amount of subsidy (BDT/ha)' variable can be written as:

$$\hat{X}_{1i} = \beta_0 + \beta_{2i} X_{2i} + ... + \beta_{ni} X_{ni} + {}_{1i} Z_{1i} + {}_{2i} Z_{2i} + u_i \tag{8}$$

Where, $\hat{X}_{1i}$ is the predicted value of instrumental variable, Z_{1i} is the dummy for credit access and Z_{2i} is the dummy for having fertilizer purchasing capability in season, $E(u_i) = 0$ and u_i is not correlated with explanatory variables included in equation 6. Thus, in second stage of 2SLS when 'amount of subsidy (BDT/ha)' variable is endogenous, its predicted

value obtained from equation 8 is included in equation 6 along with other explanatory variables which can be written as:

$$IE_i = \alpha_0 + \alpha_{1i} \hat{X}_{1i} + \alpha_{2i} X_{2i} + ... + \alpha_{ki} X_{ki} + e_i \qquad (9)$$

Where, $\hat{X}_{1i}$ the predicted value of the endogenous variable from the first stage regression, Xi's are vector of other explanatory variables; and e_i is the error term. In the absence of endogeneity, IV method is not followed and the original regression in equation 6 is estimated. This procedure is followed for three farm size groups separately to test for endogeneity.

2.1 Data

The efficiency scores for four farm size groups have been estimated using DEA approach. The output is measured as kilograms of paddy harvested per farm per year. The inputs, for which both quantities and the corresponding prices are used, are farm sizes, total labor used for paddy cultivation, amount of fertilizer and seed used, power tiller and irrigation cost per farm. These are the main inputs used in rice production in Bangladesh. Additional variables that could be considered are manure use and pesticides use. However, these two inputs are not used by all farms and hence, are excluded from DEA analysis. Input prices for all inputs are also obtained from field survey for the allocative and economic efficiencies. The amount of rental payment for land, which is existent in the study regions, is assumed as the price for land. Standard labor wage rate in the country which is BDT per man-day of labor is considered as price for labor. Here, the weighted fertilizer price is used as farmers use a combination of

different nutrients in paddy field which is calculated by applying the following formula:

$$\text{Weighted average price of fertilizer} = \sum(Q_f \times P_f)/\sum Q_f \qquad (10)$$

Where, Q_f = Quantity consumed for different fertilizers (urea, TSP, MoP & DAP) and P_f = Market prices of respective fertilizers. Bangladeshi Taka (BDT) per kilograms is the price for seed input. For irrigation and land cultivation, there are fixed rates for a unit of land. These rates have been used for pricing the respective inputs.

Table 1 shows the descriptive summary of explanatory variables used in Tobit model for estimating the impact of fertilizer subsidies on economic inefficiencies. Here, medium and large farm groups are merged together into a single group for a better econometric estimation as the number of large farms were very few in study regions which is very common in Bangladesh. Across farm size groups, the differences among these variables are prominent. Small farmers have the highest average farming experience while medium and large farmers have lowest. All groups of farmers have less than secondary level of education while marginal farmers do not have even primary education. All farm families have, on average, more than three members who are able to involve themselves in various income generating activities. Marginal and small farmers earn more from off-farm income generating activities than medium and large farmers. This indicates that agriculture contributes mostly to the annual income of medium and large farmers.

The amount of fertilizer subsidy increases with farm sizes. Amount of total subsidy, availed by a farmer, is calculated by multiplying the unit subsidy on different nutrient fertilizers by their respective usage in the field for that particular farmer. The data on subsidy per unit

Table 1: Summary statistics of explanatory variables in economic inefficiency model

Variables	Farm size category		
	Marginal	Small	Medium & Large
Farming experience (years)	23.19 (13.39)	26.47 (13.14)	22.62 (12.96)
Years of schooling	3.37 (3.35)	5.32 (4.43)	7.47 (4.37)
No. of working member	3.07 (1.18)	3.28 (1.19)	3.54 (1.22)
Share of off-farm income (%)	43.43 (15.85)	38.17 (15.42)	33.07 (11.06)
Amount of fertilizer subsidy received (BDT/ha)	16262.28 (4036.88)	23505.72 (4879.94)	26014.51 (5800.78)
Percent of farmers assessing good soil fertility	0.42 (0.50)	0.63 (0.48)	0.62 (0.49)
Percent of farmers receiving extension services	0.26 (0.44)	0.35 (0.48)	0.61 (0.49)

Source: Author's calculation

Note: Figures in the parentheses indicate standard deviation

of fertilizer, at farmer level, is obtained from ministry of agriculture and other research organizations. Currently, the market price of four basic nutrients namely, urea, TSP, MoP and DAP are subsidized by government. On average, medium and large farms enjoy almost 1.6 and 1.1 times more fertilizer subsidy per hectare of land than marginal and small farmers, respectively. This supports the disproportionate benefit incidence of subsidy policy in the country. Almost two-thirds of small and medium & large farmers assess a good soil fertility of their field while less than half of the marginal farms have fertile lands. Only around one-third of marginal and small farmers have contacts with extension agents while more than 60 percent large farms are getting services from extension offices.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results and discussion

3.1 Estimation of farming efficiencies

The frequency distribution of farms according to efficiency scores and the summary statistics are presented in Table 2. The estimated mean technical efficiency score is about 88 percent, 93 percent, 92 percent and 91 percent for marginal, small, medium and large farms, respectively. Small farmers are the most technically efficient in the study areas as observed. This result is not surprising in Bangladesh and is supported by the findings from other researches. Rahman et al. (2012) also found in their studies that the average technical efficiency in rice production is higher for small farmers. Small farmers are more productive in using scarce resources to maximize their farm production. Thus, it can be deduced that about 12 percent, 7 percent, 9 percent and 10 percent of the output is lost due to the inefficiency in rice producing system or in the inefficiency among the sampled farmers or both combined. However, the average allocative and economic efficiencies vary according to the farm size categories. The mean scores are lower than technical efficiency score. That means, although farmers are more technically efficient in rice production, on average, they are not using inputs in cost minimizing levels given the input prices they face. The allocative efficiency scores indicate that, on average, marginal, small, medium and large farmers can reduce the inputs costs by taking more notice of relative input prices when selecting input quantities by approximately 25 percent, 21 percent, 16 percent and 12 percent, respectively. The results of economic efficiency

scores indicate that sampled farmers, on average, are economically inefficient and that the total cost of rice production for marginal, small, medium and large farms could be reduced by about 31 percent, 27 percent, 23 percent and 18 percent, respectively to achieve the same level of output. For a land scarce country like Bangladesh, this gain in production and input cost will help to secure more profits from rice farming for the farmers.

The distribution of efficiency scores explores that about 74 percent of marginal farmers have technical efficiency of more than 80 percent, while 70 percent and 83 percent farmers have allocative and economic efficiency scores less than 80 percent. Despite high technical efficiency of most marginal farms, majority of them does not use inputs in the right combinations to achieve cost minimization and are, therefore, allocatively and economically inefficient. This situation is also prevalent in case of small farmers while the extent of distributional inefficiency is lower in case of medium and large farmers.

One plausible reason behind this situation could be that the capital constraint farmers were less economic in the sense of using more of low-priced inputs in the surveyed regions and consequently, they act irrationally in cost allocation for different inputs. The researcher revealed from the field survey that the marginal and small farmers were more persuaded towards extensive use of those fertilizers for which market price is comparatively lower (in this case, urea fertilizer[2]). All farmers have equal access to subsidized fertilizers through their purchases in open market in Bangladesh as has been revealed from field survey. Under current marketing system, they do not face difficulties in accessing fertilizers as local dealers and village level shops are available for supplying required amount of fertilizers in time. Capital is still a problem (especially for buying non-nitrogenous fertilizers) for marginal and small farmers in the study areas. They consider government support as an important factor for influencing their farm production. As medium and large farmers are comparatively more cost effective because they have higher allocative efficiency, more advanced technology is needed for increasing their rice production. These findings are also supported by Rahman et al. (2012). Although all farms in Bangladesh use similar technologies in rice cultivation, there are some differences among them in terms of using different varieties of seed, types of nutrient fertilizers used in the field, extent of mechanization of the farm, etc. Medium and large farms could enjoy some economies of scale being the owner of larger farm could make them more cost effective.

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[2] Urea fertilizer comprises the largest share of subsidy and it is also the cheapest in the market (MoFDM 2015).

Table 2: Distribution of farms according to efficiency scores and summary statistics

Particulars	Farm size categories			
	Marginal	**Small**	**Medium**	**Large**
Distribution of farms according to efficiency scores (%)				
Technical efficiency				
60-70%	11.63	0.00	3.53	0.00
70-80%	13.95	8.97	16.47	0.00
80-90%	48.84	26.28	23.53	46.67
90-100%	25.58	64.74	56.47	53.33
Allocative efficiency				
50-60%	9.30	1.28	1.18	0.00
60-70%	32.56	19.23	0.00	0.00
70-80%	27.91	36.54	7.06	13.33
80-90%	23.26	30.13	52.94	53.33
90-100%	6.98	12.82	38.82	33.33
Economic efficiency				
40-50%	4.65	0.00	0.00	0.00
50-60%	23.26	8.97	10.59	0.00
60-70%	27.91	35.90	21.18	0.00
70-80%	25.58	25.64	31.76	20.00
80-90%	13.95	20.51	14.12	46.67
90-100%	4.65	8.97	22.35	33.33
Mean efficiency scores (%)				
Technical efficiency	87.63 (12.12)	93.38 (6.22)	91.94 (9.08)	90.39 (3.84)
Allocative efficiency	74.63 (11.70)	78.56 (9.94)	83.59 (5.23)	87.48 (5.14)
Economic efficiency	68.68 (13.54)	73.47 (11.46)	76.96 (13.74)	82.20 (5.34)

Source: Author's estimation

Note: Figures in parentheses indicate standard deviation

Table 3: Endogeneity test results

Tests	Farm size category		
	Marginal	**Small**	**Medium-Large**
Durbin Wu-Hausman tests of endogeneity (null hypothesis, Ho: there is no endogeneity)			
Test statistic (F)	0.67	0.53	0.71
P-values (prob > F)	0.308	0.198	0.549

Source: Author's estimation

3.2 Estimation of determinants for differential economic inefficiency among the farm size groups

The Durbin-Wu-Hausman test for endogeneity reveals that the variable 'amount of fertilizer subsidy' is not endogenous. The test statistic is insignificant in all the models for three farm size groups (Table 3). Hence, the null hypothesis of no endogeneity is accepted and the original Tobit regression of inefficiency (equation 6) is estimated.

The influence and significance of the influence of fertilizer subsidy on economic inefficiency vary notably among the farm size groups as can be seen from Table 4. The farming experience has a significant negative impact on economic inefficiency for all farm categories. Results suggest that farmers with greater experience in the farming activities exhibit greater efficiency than those with less time involved in farming. This is due to the skills and know-how that come with the time spent on farming in uncertain production environment. Rice farmers'

Table 4: Maximum likelihood estimates for factors explaining efficiency differentials among farms (Tobit estimation results)

Variables	Marginal	Small	Medium & large
Farming experience (years)	-0.0251* (0.0064)	-0.0362** (0.0091)	-0.0553* (0.0108)
Years of schooling	-0.0334 (0.0899)	-0.0782** (0.0218)	0.0194 (0.0306)
No. of working member	-0.0083 (0.0171)	-0.0044 (0.0883)	-0.0011 (0.0187)
Share of off-farm income	-0.0721*** (0.0154)	-0.0491** (0.0105)	-0.0194** (0.0082)
Amount of fertilizer subsidy received (BDT/ha)	-0.0012*** (0.0004)	-0.0017*** (0.0005)	-0.0002 (0.0064)
Soil fertility assessment (1= good/average)	-0.0457 (0.0189)	-0.0586 (0.0712)	-0.0322** (0.0103)
Extension services (1=received)	-0.1832** (0.0610)	-0.1723** (0.0323)	-0.1326 (0.7622)
Constant	29.070 (41.145)	22.755 (18.509)	39.129** (12.391)
Model summary			
LR chi**2** (7)	27.99	30.67	23.80
Probability	0.0019	0.0005	0.0012
Pseudo R**2**	0.15	0.21	0.12
Number of observations	43	156	101
Left-censored observations at Economic inefficiency<=0	3	13	7

Source: Author's estimation

Note: ***, ** and * represent statistical significance at 1%, 5% and 10% level, respectively

Figures in the parentheses indicate standard errors

expertise assists them in ensuring the optimal timing and use of inputs and thereby, reduces their economic inefficiency. Several empirical researches like Sek (2015), Bäckman et al. (2011), Bozoglu and Chehan (2007), Huffman (2001: 334-381) and Kalirajan & Flinn (1983) have also reported a significant negative impact of farming experience on farm efficiency.

Education has negative and significant impact only for small farmers while having positive and insignificant effect in case of medium and large farmers. This can be explained as with increasing years of education, large farmers tend to shift to various off-farm income generating activities. This is also justified as descriptive statistics reveal that large farm households have higher level of education. This phenomenon is common in Bangladesh where educated people are moving from rural areas to urban areas for better job opportunities and pay less attention on farming activities (Asadullah and Rahman 2009). Therefore, their education does not contribute to improve agricultural production and farming efficiencies. In case of marginal farmers, the impact of education is insignificant. This is due to the fact that the primary education system in Bangladesh is not agriculture oriented.

Farmers having less than primary level of education cannot gain much knowledge from school to apply in agricultural activities. Bäckman et al. (2011), Hasnah et al. (2004), Rahman (2004), Wadud (2003), Coelli et al. (2002) did not find any significant effect of education on farming efficiency. On the other hand, Darko and Ricker-Gillbert (2013), Asadullah and Rahman (2009) argued that higher education increases efficiency significantly.

Number of working members has negative, but insignificant impact on economic inefficiency for all farm categories. The insignificant impact is justified because of the problem of underemployment of surplus labor in agriculture with the result that the number of working adults is not a significant indicator of economic efficiency. On the other hand, the significant and negative signs of share of off-farm income point towards a situation where the farm households are unable to run the production activities only with income from agriculture and hence, they engage themselves in different off-farm occupations. This also indicates that relatively higher off-farm income increases the economic efficiency of rice farmers. Marginal farmers' farming efficiency is affected mostly by a change in this variable. As large farmers can generate

more income from agriculture, they are comparatively less dependent on off-farm income than marginal and small famers. However, Asadullah & Rahman (2009), Coelli et al. (2002), Abdulai and Eberlin (2001) showed that off-farm income variable is positively and insignificantly related with farming inefficiency.

The main variable of interest, amount of subsidy a farmer is enjoying, appears with negative sign in all the models. This implies that efficiency increases with the quantity of subsidized fertilizer that a farmer uses for rice production. But the variable has significant impact only for marginal and small farmers while having insignificant influence for medium and large farmers in the estimated models. The research conducted by Sek (2015), Darko and Ricker-Gillbert (2013), Ricker-Gilbert and Jayne (2010), Yawson et al. (2010) reported a positive and significant impact of fertilizer subsidy program on farm efficiency as the farmers, who get subsidized fertilizer, can overcome the extent of their budget constraint. Such an income effect transforms to a greater efficiency and an increase in overall productivity. It can be realized from the magnitude of estimated coefficients that there is differential impact of fertilizer subsidy on farming efficiency of different farm groups in the study areas. Results can be interpreted as on average, if farmers get BDT 1000 more subsidy per hectare of land on fertilizer, this will reduce their economic inefficiency by 12 percent, 17 percent and 2 percent for marginal, small and medium & large farm categories, respectively, all else being equal (Table 4).

Medium and large farmers' fertilizer use intensity was higher than the marginal and small farmers in study areas. Moreover, as they are comparatively more financially solvent, they use the required amount of fertilizers in field based on their managing capabilities regarding optimum input combination. Therefore, the findings from the model indicate that any further increase in the amount of subsidy per unit of fertilizer would just add to the amount of their extra profit from farming without bringing a significant improvement in their efficiency levels. The results are also justified from the fact that although the technical efficiency level is satisfactory for marginal and small farmers, they are more allocatively and economically inefficient than medium and large farmers as revealed in Table 2.

Among other variables, soil fertility assessment significantly influences economic efficiency of medium and large farmers. While assessing a good quality of soil in the field, medium and large farmers cultivate them in an economic way to get maximum output with minimum costs which reduces their inefficiencies. On the other hand, marginal and small farmers cannot properly cultivate in

a cost-effective way due to resource constraints. Thus, despite having fertile soil, they do not get full benefit out of it. Extension visits are negatively related with economic inefficiency. Marginal and small farmers who get services from extension agents significantly reduce their economic inefficiencies by 18 percent and 17 percent, respectively. Although having insignificant impact on large farmer's efficiency, this variable is an important policy tool for improving the productivity of smallholder farmers.

4 Conclusion

This study has analyzed the influences of fertilizer subsidy on farming efficiencies of 300 farm households in Bangladesh. Data Envelopment Approach (DEA) explore that although most of the farms are technically efficient, they are, in general, economically inefficient which relates to their usage of inputs in a cost minimizing way. Fertilizer subsidy has a significant inefficiency-reducing impact in case of marginal and small farms. On the other hand, it imposes an insignificant impact in reducing medium and large farms' farming inefficiency. Empirical results based on survey data support the major drawback of universal subsidy policy. The finding points to the fact that as the land distribution is skewed in the country, subsidy benefits are unequally distributed among the farm size groups. Thus, the current subsidy policy is distorting the resources by adding to the profit of large farm holders who are already more solvent than other groups. This further implies that part of the subsidy goes to reducing the cost of production for produce (by large farms) that would be produced anyway. Because fertilizer subsidy improves the efficiency of marginal and small farm holders, policy interventions should favor these farms for acceleration of agricultural growth in the country.

Apart from subsidy support, income from off-farm activities and extension services also significantly influence the farming efficiencies of the farmers. There could be several ways to favor the intended farmers in terms of providing subsidy. The lack of purchasing power of smallholder farmers should be addressed rather than subsidizing one of the many production inputs needed by farmers. Based on the findings from this research, subsidy could be targeted to the financially constrained farmers. A plausible alternative could be direct cash payment. Direct cash could be given to farmers only for subsistence farming and not for the production of commercial crops. The sample distribution of the study is dominated by smallholders which represents the overall situation of Bangladesh agriculture, this policy intervention is

expected to improve farm production more effectively. In one hand, fertilizer subsidy helps to loosen their budget constraint and makes them able to buy adequate amount of fertilizer for rice cultivation. On the other hand, it makes easier for them to save some money which they were supposed to spend on fertilizers and use that savings for buying other costly inputs.

However, such targeting may be administratively costly as it will require detailed database of the farmers. However, revised policy would help to save costs for providing subsidy to large farm holders which can be utilized for administrative costs. Furthermore, the success of revised subsidy policy will be augmented by putting equal emphasis on other efficiency enhancing factors. The investments by the government in the research and development, technology transfer, extension, creating income generating activities in rural areas, etc. must continue and be strengthen. The extension services should be enhanced to educate and motivate farmers to invest in buying additional fertilizer.

Conflict of interest: Authors declare no conflict of interest.

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