# EFFICIENCY EVALUATION OF RICE PRODUCTION IN BANGLADESH[1]

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## ABSTRACT

The purpose of this paper is to compare and explain the production efficiencies across rice varieties grown in Bangladesh. Specifically, this study compares the efficiencies among three main rice varieties (Local Aman, HYV Aman and HYV Boro), between two monsoon season varieties (Local Aman and HYV Aman), and between high yielding varieties of monsoon (HYV Aman ) and dry season (HYV Boro) across the seven administrative divisions of Bangladesh. Result indicates that HYV Boro is more efficient (technical, cost and allocative) among all three main rice varieties in Bangladesh. HYV Aman is more efficient than Local Aman in all seven divisions and HYV Boro is more efficient than HYV Aman across all divisions except Sylhet. Several determinants of these efficiency scores were identified using the Tobit regression. The coefficient estimates suggest that off-farm activities of households, loan status, farm subsidies, extension services, household head characteristics (age, literacy, gender and occupation), and dependency ratio of households are the key explanatory variables of these efficiency scores.

## INTRODUCTION

Bangladesh is a densely populated country with a population density of 1,203 per square kilometer[3]. It is characterized as an agricultural country where 80% of the people are involved in agriculture and nearly 70% of rural population has agriculture as their main source of income. The agricultural sector is crucial to the economy of the country contributing 20.24% of the country's GDP, employing 48.1% of country's labor force, providing food sufficiency and bringing overall development to the country (BBS, 2013). Bangladesh is one of the biggest producers of rice in the world and at the same time it is one of the largest importer. Rice is a major staple food for millions of Bangladeshi and it contributes about 71% of the total calorie intake (HIES, 2010). There is a challenge within the country to increase rice productivity faster than the country's annual population growth. However, the increasing population of the country has led to higher land fragmentation; with the farm size (land holding per farm) decreasing from 2.26 acres in 1983/84 to 1.48 acres in 2008/2009 (BBS, 2013). Additionally, the impact of climate change and associated natural disasters (such as floods) has affected rice production adversely in several rice growing areas of the country. Hence, increasing rice productivity by tacking various problems confronting rice production could be a major strategy for the country to reduce poverty and achieve its food security goals.

Rice is produced in all seven divisions of the country and in all three seasons; Boro, Aman and Asus (Appendix 1). According to the BBS (2013), rice is produced on nearly 77% percent (28,487,000 Acres**)** of total cultivated land. In terms of rice varieties, Local Aman and HYV Aman are monsoon season varieties and dry season varieties are Local Asus, HYV Asus, Local Boro and HYV Boro. Aman is planted between April and May and harvested between July and August,

[3] http://data.worldbank.org/indicator/EN.POP.DNST

while Boro is planted in December and harvested in February. In 2011, Local Aman, HYV Aman and HYV Boro accounted for over 84% of total rice production in Bangladesh. However, all of these varieties are not performing with same level of efficiency. Among these three varieties, HYV Boro is cultivated on nearly 35% of annual rice land, but it has contributed nearly 46% of total rice production. Whereas, HYV Aman and local Aman are cultivated on nearly 34% and 15% percent of rice land and have contributed 8% and 30% of total production, respectively. Hence, the purpose of this paper is to compare and explain the production efficiencies scores across three major rice varieties grown in Bangladesh. The specific objectives are to:

- compare the efficiencies of three main rice varieties (Local Aman, HYV Aman, HYV Boro) in Bangladesh
- compare the efficiencies between monsoon season varieties (Local Aman and HYV Aman) in each divisions
- compare the efficiencies of HYV varieties of monsoon season (HYV Aman) and dry season (HYV Boro) within each divisions
- explain the determinants of rice efficiency in Bangladesh.

Different researchers have studied the efficiency of rice production and its determinants in Bangladesh. Coelli et al. (2002) estimated efficiency of Bangladeshi modern Aman and modern Boro rice producers using Data Envelopment Analysis (DEA) approach. They have found that the average Allocative Efficiency (AE) and Cost Efficiency (CE) were respectively 78% and 51.7% for modern Aman and 81.3% and 56.2% for modern Boro. They identified overuse of labor and fertilizers as the cause for low allocative efficiency in the farms. Rahman (2003) argued that considerable amount of profit can be obtained by improving the efficiency of modern rice production in Bangladeshi. Similarly, Hossain et al. (2012) found that Technical Efficiency (TE) of Boro rice is higher than that of Aus and Aman rice. Another study in 2012 found that a TE of 80% and 86% for inbred HYV and hybrid rice at the farm level in Bangladesh (Salam, 2012). This study concluded that education, farm experience, extension contact, and land type were the major factors associated with efficiency for both inbred and hybrid rice growers. Nargis and Lee (2013) showed that on average, the farms TE and AE for Boro rice are 0.93 and 0.82, respectively. They found education, seed type, land tenancy, type of irrigation machine, and extension services as major factors impacting technical efficiency.

Most of the previous rice research studies in Bangladesh are focused on the whole country or one particular region. Therefore, this study contributes to the existing knowledge of rice research in Bangladesh by comparing the efficiencies of three major rice varieties across the seven divisions of Bangladesh. Additionally, the paper identifies the key explanatory factors impacting these efficiency scores in Bangladesh.

## DEA MODEL

Data Envelopment Analysis (DEA) is a nonparametric method that tries to map out the frontier of the production set. It is a linear programming technique that compares efficiency of a Decision Making Unit (DMU) relative to the "best" DMU in a group using some efficiency criteria. CCR model developed by Charnes et al. (1978) is used to estimate the technical efficiency. It has following efficiency measure:

$$\theta_n = \frac{\sum_{s=1}^{S} u_s \, y_{sn}}{\sum_{m=1}^{M} v_{m x_{mn}}}$$

Here, $\theta_n$ is the efficiency for each of the DMUs *n*. $\sum_{s=1}^{s} u_s \, y_{sn}$ is the virtual output, $\sum_{m=1}^{M} v_{m x_{mn}}$ is the virtual input, S is the number of outputs (y), M is the number of inputs (x), and

$u_s$ and $v_m$ are the variable weights. Thus, the efficiency for decision making unit *n* is the weighted sum of output to weighted sum of input.

CCR model assume input and output data as nonnegative, less input is better, more output is better and measurement units of inputs and outputs can differ without effecting outcome of analysis. The objective of CCR model is to maximize θ for each of the DMU *n* subject to the constraints listed, that is:

$$Max\ \theta_n = \sum_{s-1}^{S} u_s\, y_{sn}$$

Subject to:

$$\sum_{m=1}^{M} v_{mX_{mn}} = 1$$

$$\sum_{s=1}^{S} u_s\, y_{sn} \ \le \sum_{m=1}^{M} v_{mX_{mn}}\ for\ n = 1, \dots., N$$

$$(\, u_s, v_m) \ge 0\ for\ s = 1, \dots, S\ and\ m = 1, \dots., M$$

The cost efficiency model measures how far a DMU *n* has come from meeting the minimum cost. The cost efficiency DEA model is given by:

$$min \sum_{m=1}^{M} C_m\, x_m$$

Subject to:

$$\sum_{K=1}^{N} \lambda_k\ x_{m,k}\ \le x_m \quad for\ m = 1, \dots., M$$

$$\sum_{k=1}^{N} \lambda_k\ y_{s,k}\ \ge y_{s,n}\ for\ s = 1, \dots., S$$

$$(\lambda_1, \dots \dots \lambda_N, x_1, \dots x_m) \geq 0$$

Cost efficiency for DMU *n* is the following ratio:

$$\frac{\sum_{m=1}^{M} C_m \ x_m}{\sum_{m=1}^{M} C_m \, x_{m,n}}$$

Here, $x_m$ is the optimal input used, $x_{m,n}$ is the current input used, $c_m$ is the price of input, $\lambda_k$ is the weights of the DMUs.

The relationship between technical efficiency and cost efficiency is used to determined allocative efficiency. Allocative efficiency is the ratio of cost efficiency and technical efficiency.

$$Allocative\ Efficiency\ = \frac{Cost\ Efficiency}{Technical\ Efficiency}$$

In this study, inputs considered are fertilizer in (kg), seed (kg) and labor (hours). The output is rice yield (Metric tons per Hectares). DMUs are the varieties for each divisions and for whole the country, and the technically efficient rice production (for each DMU) will have a θ =1 while inefficient production will have θ < 1. Also, the cost efficiency model measures which rice variety is cost efficient. Data is analyzed using the General Algebraic Modeling System (GAMS) software to estimate the technical, allocative and cost efficiency for each DMU.

**DATA**

We obtained the average value of inputs and outputs per division for each of three varieties from two different sources. First, 2011–2012 Bangladesh Integrated Household Survey (Ahmed, 2013) data on division level aggregate input cost of each varieties such as seed/seedling cost (Taka), fertilizer cost (which include aggregate cost of Urea, TSP, DAP, MoP) (Taka) and labor cost (Taka) was obtained (Appendix 2). Second, division level aggregate data related to total production (Metric tons), total cultivated area (Hectares), seed per hectare (Kg), was obtained from

BBS (2013). We used the household level survey dataset obtained from the Bangladesh Integrated Household Survey (BIHS) (Ahmed, 2013) to analyze the impact of different household characteristics on division level aggregate rice production efficiency.

## ECONOMETRIC MODEL

We used a Tobit model to assess the determinants affecting TE, AE and CE of all these three rice varieties under consideration. Description of all the dependent and independent variables is presented at table 1. We estimated three separate Tobit regressions for TE, AE and CE for each varieties. The estimates obtained are presented in the regression tables 2, 3 and 4 respectively for HYV Aman, Local Aman and HYV Boro. Following Griffiths et al. (1993) our econometric model becomes:

$$y_{ijk} = \begin{cases} y_{ijk}^{*} & if\ y_{ijk}^{*} > 0 \\ 0 & Otherwise \end{cases}$$

Here, $y_{ijk}$ is an observed variable which is assumed to be related with a latent variable $y_{ijk}^{*}$ . This variable $y_{ijk}$ represents the efficiency score for a specific division $i$ (Barisal, Chittagong, Dhaka, Khulna, Sylhet, Rajshahi and Rangapur) for a rice variety $j$ (Local Aman, Hyv Aman and HYV Boro) and for the rice efficiency category $k$ (technical, allocative and cost). Here, the latent variable regression is:

$$y_{ijk}^{*} = \beta X_{ijk} + \mu_{ijk}$$

Where, $y_{ijk}^{*}$ is a dependent variable that represents efficiency scores in the range of 0 to 1 and is censored at the left side with the minimum value of 0; therefore, we are using Tobit regression for estimation of the regression. $X_{ijk}$ are the explanatory variables that represents a household which is in division $i$ , produces rice variety $j$ with a particular rice efficiency category $k$. $\mu_{ijk}$ is the random error term associated with this regression model. Therefore, in total we will estimate and interpret the coefficients of nine separate Tobit regression models.

## RESULT AND DISCUSSION

This study has compared the efficiencies of the major three rice varieties within each division of Bangladesh (Appendix 3). At the country level, HYV Boro is efficient in term of cost, technical and allocation as compared with other varieties. There is a 10% different in the degree of inefficiency (CE and AE) between HYV Aman and Local Aman. The TE of HYV Aman and Local Aman are 91.6% and 86.1%, respectively, while the CE of the Monsoon varieties are 75.5% and 61.9%, respectively.

In most cases, the division level results are similar to that of country level results. In Rangpur, HYV Boro is technically efficienct (100%) while HYV Aman is inefficient with a value of 92.5%. Although both HYV Aman and Local Aman are inefficient in this division, HYV Aman CE value (76%) is higher than the Local Aman (63%). In Rajhansi, the AE of HYV Aman (82.5%) is higher than the AE of Local Aman (72.6%). In Barisal and Khulna, HYV Boro and HYV Aman is technically efficient while cost and allocative inefficient. Local Aman is inefficient in both of these divisions. In Chittagong, TE and CE of both HYV Aman and Local Aman are below 50%. In Dhaka, although Local Aman is technically inefficient, its efficiency (93%) is higher than that of HYV Boro (80.9%). In Sylhet, HYV Aman is efficient compared to HYV Boro which has TE and CE of 89% and 70% respectively. Local Aman is inefficient with a CE of 46%.

We have interpreted tobit regression coefficients at least at the 10 percent level of statistical significance to understand the relationship between the explanatory variables and the efficiency scores of each varieties.  Our result suggests that involvement in off farm activities is likely to have a significant positive effect on TE, AE and CE of HYV Aman and Local Aman. This is consistent with the findings of Mishra et al. (2015). They found that off farm income can provide an opportunity for farmers in Bangladesh to adopt improved agricultural technologies that leads to positive impact on rice farmer's TE Mishra et al. (2015). Whereas, off farm activities involvement is likely to have a negative impact on TE, AE and CE of HYV Boro. This result is also consistent with the findings of Coelli et. al (2002). They argued that households in Bangladesh which give more importance to non-agricultural work activities are likely to pay less attention to their agricultural crops, resulting in negative impact on efficiency scores of rice production (Coelli et al., 2002). They have used percentage of income earned off-farm as their explanatory variable. The reason behind this might also be that Boro rice is a labor intensive rice variety that requires human labor as a major input during production (Majumder, 2009).

Agricultural subsidies are likely to have a positive effect on TE, AE and CE of HYV Aman and AE of Local Aman; whereas, they are likely to have negative effect on TE and CE of Local aman and HYV Boro. The negative impact of a subsidy is supported by Selim (2007) who argued that higher input subsidies likely result in technical inefficiency in rice production in Bangladesh due to interaction of low labor productivity and the use of innovative technologies. Additionally, income of the household play a significant role in rice production efficiency. Households with loans are likely to have a significant negative effect on TE, and CE of HYV Aman and HYV Boro. Also, loans are likely to have a negative effect on AE of HYV Boro. Whereas, higher income from agricultural sector likely to have positive effect on AE of HYV Aman; TE and AE of Local Aman; and TE, AE and CE of HYV Boro. Low agricultural income will likely inhibit the purchase and adoption of new agricultural technologies. There is a positive effect from access to extension services on TE, AE and CE of HYV Boro, but it has no effect on Local Aman and HYV Aman.

The result is consistent with Islam et al. (2012) and Bäckman, et al., (2011) who argued that extension services provide information which allows farmers to allocate inputs more efficiently.

Several households' characteristics have a significant impact on efficiency of rice production in Bangladesh. Male headed households are likely to have a higher TE and CE for HYV Aman, Local Aman and HYV Boro than female headed households. Age of household heads is likely to have a negative effect on CE of HYV Aman, TE and CE of Local Aman. This is supported by Islam et al. (2012) and Bäckman, et al. (2011), as younger farmers are usaually more efficient in producing Local Aman than older farmers. Household head literacy is likely to have likely to have positive effect on TE, AE and CE of HYV Boro. Similarly, it has a positive effect on CE of Local Aman, but negative effect on TE of Local Aman. The positive result suggests that farmers with more education are more efficient in Boro rice production than farmers with less-education. A higher education level gives a farmer the ability to use existing and new technology nire efficiently. Similar results are obtained by Weir (1999), Tan et al. (2010) and Weir and Knight (2000). Households having farming as their main occupation are likely to have a negative effect on the AE of HYV Aman and Local Aman. This may be due to the higher labor income from off-farm activities than from agricultural activities. However, there is a positive effect of farming as the main occupation of household head on TE and CE of Local Aman and HYV Boro. This might also be because of the fact that Boro rice is a labor intensive rice variety, so farmers need to provide more labor for this crop (Majumder, 2009). Similarly, households having a higher proportion of dependents are likely to have negative effect on TE and CE of HYV Aman, and TE, AE and CE of HYV Boro. This is consistent with Chavas et al. (2005) who argued that dependency ratio reflects restrictions in labor allocation for farm production and off-farm earnings.

## CONCLUSION

This study used DEA to estimate the efficiency scores across three major rice varieties grown in Bangladesh, providing several avenues that policy makers can use to achieve rice sufficiency within the country and reduce imports. Result shows that HYV Boro is more efficient (technical, cost and allocative efficiency) among all three main rice varieties in Bangladesh. HYV of the Dry season (HYV Boro) is more efficient than HYV of Monsoon season (HYV Aman) across all divisions except (Sylhet). Similarly, HYV of Monsoon (HYV Aman) is more efficient than the local variety of Monsoon (Local Aman). Since varietal performance depends on both genetic and environmental factors, genetic improvement of HYV Aman is highly recommended. Based on the Tobit regression estimates, we recommend policy makers to increase extension services, manage the interaction of subsidies with labor productivity to encourage more allocation of time in the Boro rice farming regions of Bangladesh. Also, we recommend policy makers to focus on increasing off-farm income opportunities, providing subsidies, educating household's heads and managing dependency ratio to enhance rice production efficiency in the Aman rice farming regions of Bangladesh.

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Table 1. Description of dependent and independent variables

| Variable | Variable label | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| *Dependent variables* | | | | | | |
| localaman_te | Technical efficiency score of Local Aman | 6,503 | 0.75 | 0.18 | 0.48 | 0.93 |
| localaman_ae | Allocative efficiency score of Local Aman | 6,503 | 0.75 | 0.05 | 0.72 | 0.87 |
| localaman_ce | Cost efficiency score of Local Aman | 6,503 | 0.56 | 0.12 | 0.34 | 0.67 |
| hyvaman_te | Technical efficiency score of HYV Aman | 6,503 | 0.85 | 0.17 | 0.49 | 1.00 |
| hyvaman_ae | Allocative efficiency score of HYVAman | 6,503 | 0.86 | 0.06 | 0.82 | 1.00 |
| hyvaman_ce | Cost efficiency score of HYV Aman | 6,503 | 0.74 | 0.18 | 0.40 | 1.00 |
| hyvboro_te | Technical efficiency score of HYV Boro | 6,503 | 0.99 | 0.03 | 0.89 | 1.00 |
| hyvboro_ae | Allocative efficiency score of HYV Boro | 6,503 | 0.98 | 0.07 | 0.79 | 1.00 |
| hyvboro_ce | Cost efficiency score of HYV Boro | 6,503 | 0.97 | 0.09 | 0.70 | 1.00 |
| *Independent variables* | | | | | | |
| bang_off_farm | Does anyone in your household own or operated any non-farm activities? (1=Yes, 0= No) | 6,503 | 0.38 | 0.49 | 0.00 | 1.00 |
| loan | Did any adult in the household ever have any loans? (1= Yes, 0= No) | 6,503 | 0.80 | 0.40 | 0.00 | 1.00 |
| subsidy | (Do you have an agriculture input subsidy card? (1= Yes, 0= No) | 6,503 | 0.09 | 0.28 | 0.00 | 1.00 |
| extension | Did any agricultural extension agent visit your farm during the last 12 months? (1= Yes, 0= No) | 6,503 | 0.05 | 0.21 | 0.00 | 1.00 |
| hh_literacy | Can household head read or write? (1= Yes, 0= No) | 6,503 | 0.77 | 0.42 | 0.00 | 1.00 |
| agri_market | Total annual income from marketing of agricultural commodities(10000TK) | 3,735 | 2.94 | 7.35 | 0.00 | 215.78 |
| land_total | Polt size/area in decimal | 6,503 | 91.31 | 145.42 | 0.25 | 2695.00 |
| hh_sex | Gender of household head (1= Male, 0= Female) | 6,503 | 0.82 | 0.38 | 0.00 | 1.00 |
| hh_occup | Is farming is the household head main occupation? (1= Yes, 0= No) | 6,503 | 0.42 | 0.49 | 0.00 | 1.00 |
| hh_age | Age of househol head (years) | 6,503 | 44.17 | 13.98 | 17.00 | 95.00 |
| depen_ratio | Dependency ration of the household | 6,503 | 39.71 | 22.05 | 0.00 | 100.00 |

Table 2. Tobit Regression Coefficient Estimates for HYV Aman

| Variables | TE | AE | CE |
|---|---|---|---|
| bang_off_farm | 0.024** (0.008) | 0.005** (0.002) | 0.022*** (0.006) |
| loan | -0.058*** (0.010) | -0.000 (0.002) | -0.030*** (0.007) |
| subsidy | 0.109*** (0.013) | 0.025*** (0.003) | 0.075*** (0.009) |
| extension | -0.010 (0.016) | -0.005 (0.004) | -0.015 (0.011) |
| hh_literacy | 0.008 (0.010) | -0.002 (0.002) | -0.003 (0.007) |
| agri_market | 0.001 (0.001) | 0.000* (0.000) | 0.000 (0.000) |
| hh_sex | 0.065*** (0.013) | -0.002 (0.003) | 0.044*** (0.009) |
| hh_occup | 0.001 (0.008) | -0.004* (0.002) | 0.001 (0.006) |
| hh_age | -0.000 (0.000) | -0.000 (0.000) | -0.000** (0.000) |
| depen_ratio | -0.001*** (0.000) | -0.000 (0.000) | -0.000*** (0.000) |
| _cons | 0.939*** (0.023) | 0.863*** (0.005) | 0.762*** (0.017) |
| /sigma | 0.224 (0.004) | 0.057 (0.001) | 0.173 (0.002) |
| *Number of obs* | *3,735* | *3,735* | *3,735* |
| *LR chi2(10)* | *182.07* | *88.85* | *151.90* |
| *Prob > chi2* | *0.0000* | *0.0000* | *0.0000* |
| *Pseudo R2* | *0.084* | *-0.010* | *-0.110* |
| *Log likelihood* | *-1000.434* | *4440.505* | *764.805* |

Table 3. Tobit Regression Coefficient Estimates for Local Aman

| Variables | TE | AE | CE |
|---|---|---|---|
| bang_off_farm | 0.010* | 0.004*** | 0.009** |
| | (0.006) | (0.002) | (0.004) |
| loan | -0.003 | -0.001 | -0.003 |
| | (0.007) | (0.002) | (0.005) |
| subsidy | -0.052*** | 0.020*** | -0.026*** |
| | (0.008) | (0.002) | (0.005) |
| extension | 0.009 | -0.004 | 0.005 |
| | (0.011) | (0.003) | (0.007) |
| hh_literacy | -0.011* | -0.001 | -0.008* |
| | (0.007) | (0.002) | (0.004) |
| agri_market | 0.001* | -0.000* | 0.000 |
| | (0.000) | (0.000) | (0.000) |
| hh_sex | 0.051*** | -0.001 | 0.037*** |
| | (0.009) | (0.002) | (0.006) |
| hh_occup | 0.023*** | -0.003* | 0.015*** |
| | (0.006) | (0.002) | (0.004) |
| hh_age | -0.000* | -0.000 | -0.000* |
| | (0.000) | (0.000) | (0.000) |
| depen_ratio | -0.000 | -0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) |
| _cons | 0.723*** | 0.752*** | 0.540*** |
| | (0.016) | (0.004) | (0.011) |
| /sigma | 0.168 | 0.046 | 0.110 |
| | (0.002) | (0.001) | (0.001) |
| *Number of obs* | *3,735* | *3,735* | *3,735* |
| *LR chi2(10)* | *94.36* | *92.38* | *89.46* |
| *Prob > chi2* | *0.000* | *0.000* | *0.000* |
| *Pseudo R2* | *-0.036* | *-0.008* | *-0.015* |
| *Log likelihood* | *1361.858* | *6236.057* | *2941.810* |

Table 4. Tobit Regression Coefficient Estimates for HYV Boro

| Variables | TE | AE | CE |
|---|---|---|---|
| bang_off_farm | -0.032*** | -0.064*** | -0.090*** |
| | (0.012) | (0.024) | (0.033) |
| loan | -0.052*** | -0.104*** | -0.145*** |
| | (0.017) | (0.033) | (0.047) |
| subsidy | -0.091*** | -0.181*** | -0.253*** |
| | (0.016) | (0.032) | (0.044) |
| extension | 0.054** | 0.108** | 0.150** |
| | (0.026) | (0.052) | (0.072) |
| hh_literacy | 0.038*** | 0.077*** | 0.107*** |
| | (0.013) | (0.027) | (0.037) |
| agri_market | 0.004** | 0.008** | 0.011** |
| | (0.002) | (0.003) | (0.004) |
| hh_sex | 0.029** | 0.059 | 0.082** |
| | (0.018) | (0.036) | (0.050) |
| hh_occup | 0.007 | 0.015 | 0.020 |
| | (0.012) | (0.024) | (0.033) |
| hh_age | 0.001 | 0.001 | 0.002 |
| | (0.000) | (0.001) | (0.001) |
| depen_ratio | -0.001** | -0.001** | -0.002** |
| | (0.000) | (0.001) | (0.001) |
| _cons | 1.254*** | 1.507*** | 1.708*** |
| | (0.036) | (0.071) | (0.100) |
| /sigma | 0.193 | 0.386 | 0.538 |
| | (0.010) | (0.020) | (0.027) |
| *Number of obs* | *3,735* | *3,735* | *3,735* |
| *LR chi2(10)* | *82.59* | *82.59* | *82.59* |
| *Prob > chi2* | *0.000* | *0.000* | *0.000* |
| *Pseudo R2* | *0.063* | *0.047* | *0.042* |
| *Log likelihood* | *-618.739* | *-839.853* | *-946.326* |

## APPENDICES

## APPENDIX 1


Figure 1.1. Map of Bangladesh showing seven administrative divisions (Source:https://commons.wikimedia.org/wiki/File:Bd_map_division_-_wiki.svg)

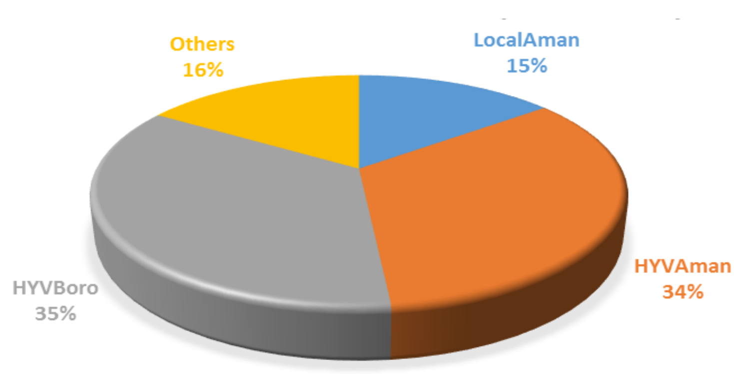



Figure 1.2. Percentage of total rice land use under each rice varieties in Bangladesh in 2012 (Source: This figure is developed based on data from BBS, 2013)

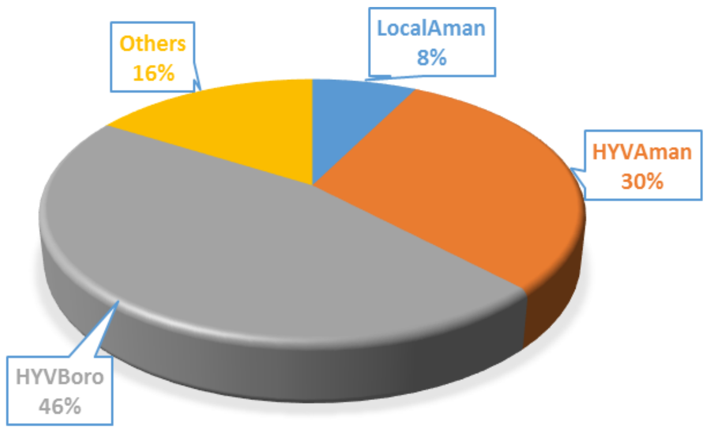



Figure 1.3. Percentage of total rice production contributed by each rice varieties in Bangladesh in 2012 (Source: This figure is developed based on data from data from BBS, 2013)

## APPENDIX 2

Table 2.1. Area and production of HYV Aman

| | Total production (Metric tons per division) | Yield (tons/ha) | Total Land (hectares) |
|---|---|---|---|
| Barisal | 959.337 | 2.5 | 383.735 |
| Chittagong | 1101.119 | 1.93 | 570.528 |
| Dhaka | 1813.164 | 1.97 | 920.388 |
| Khulna | 1224.083 | 2.43 | 503.738 |
| Rajshahi | 2088.610 | 2.36 | 885.004 |
| Rangpur | 750.429 | 2.15 | 349.037 |
| Sylhet | 491.296 | 1.66 | 295.961 |
| Total | 8428.0387 | | 3908.391 |

Table 2.2. Total cost of input use for HYV Aman ($/division)

| | Seed | fertilizer | Labor |
|---|---|---|---|
| Barisal | 2,702,261.5 | 1,693,806.1 | 8,205,020.7 |
| Chittagong | 2,154,288.0 | 2,706,098.9 | 13,878,158.2 |
| Dhaka | 2,352,295.2 | 2,017,678.4 | 11,013,576.8 |
| Khulna | 1,422,121.7 | 3,354,994.7 | 8,956,373.7 |
| Rajshahi | 1,623,966.3 | 2,716,459.7 | 8,342,014.1 |
| Rangpur | 1,305,850.0 | 2,051,063.3 | 7,838,553.8 |
| Sylhet | 1,419,051.8 | 1,587,511.5 | 8,460,588.2 |

Table 2.3. Total input use per division for HYV Aman

| | Seed(kg) | Fertilizer(kg) | Labor(hours) |
|---|---|---|---|
| Barisal | 8,530.428 | 112,818.075 | 329,474.827 |
| Chittagong | 12,682.84 | 167,735.237 | 489,855.354 |
| Dhaka | 20,460.22 | 270,594.032 | 790,245.020 |
| Khulna | 11,198.09 | 148,098.924 | 432,509.307 |
| Rajshahi | 19,673.64 | 260,191.222 | 759,864.567 |
| Rangpur | 7,759.092 | 102,616.869 | 299,683.143 |
| Sylhet | 6,579.222 | 870,12.654 | 254,112.465 |

Table 2.4. Area and production of Local Aman

| | Total production (Metric tons per division) | Yield (tons/ha) | Total Land (hectares) |
|---|---|---|---|
| Barisal | 232.07 | 1.41 | 164.588 |
| Chittagong | 320.565 | 1.31 | 244.706 |
| Dhaka | 619.782 | 1.57 | 394.765 |
| Khulna | 224.702 | 1.04 | 216.059 |
| Rajshahi | 580.771 | 1.53 | 379.589 |
| Rangpur | 218.571 | 1.46 | 149.706 |
| Sylhet | 149.791 | 1.18 | 126.941 |
| TOTAL | 2346.25 | | 1676.36 |

Table 2.5. Total cost of input use of Local Aman ($/division)

| | Seed | fertilizer | labor |
|---|---|---|---|
| Barisal | 682,548.479 | 458,872.717 | 2,802,612.852 |
| Chittagong | 1,353,225.645 | 1,327,776.193 | 8,045,452.578 |
| Dhaka | 1,865,660.917 | 1,746,836.554 | 9,588,060.166 |
| Khulna | 836,365.013 | 1,289,225.015 | 4,220,499.657 |
| Rajshahi | 1,288,704.073 | 2,219,455.881 | 7,325,305.217 |
| Rangpur | 712,451.408 | 805,269.200 | 4,143,565.889 |
| Sylhet | 284,348.680 | 289,934.100 | 1,853,471.015 |

Total 2.6. Total input use per division of Local Aman

| | Seed(kg) | Fertilizer(kg) | Labor(hours) |
|---|---|---|---|
| Barisal | 3,555.111 | 33,411.464 | 112,463.317 |
| Chittagong | 5,285.655 | 49,675.372 | 167,207.791 |
| Dhaka | 8,526.931 | 80,137.361 | 269,743.145 |
| Khulna | 4,666.878 | 43,860.010 | 147,633.225 |
| Rajshahi | 8,199.119 | 77,056.532 | 259,373.047 |
| Rangpur | 3,233.652 | 30,390.342 | 102,294.189 |
| Sylhet | 2,741.934 | 25,769.099 | 86,739.041 |

Table 2.7. Area and production of HYV Boro

| | Total production (Metric tons per | Yield (tons/ha) | Total Land (hectares) |
|---|---|---|---|
| Barisal | 1419.717 | 3.53 | 402.186 |
| Chittagong | 2074.923 | 3.47 | 597.961 |
| Dhaka | 3636.703 | 3.77 | 964.643 |
| Khulna | 1863.695 | 3.53 | 527.959 |
| Rajshahi | 3663.853 | 3.95 | 927.558 |
| Rangpur | 1364.507 | 3.73 | 365.820 |
| Sylhet | 899.557 | 2.9 | 310.192 |
| TOTAL | 14922.956 | | 4096.318 |

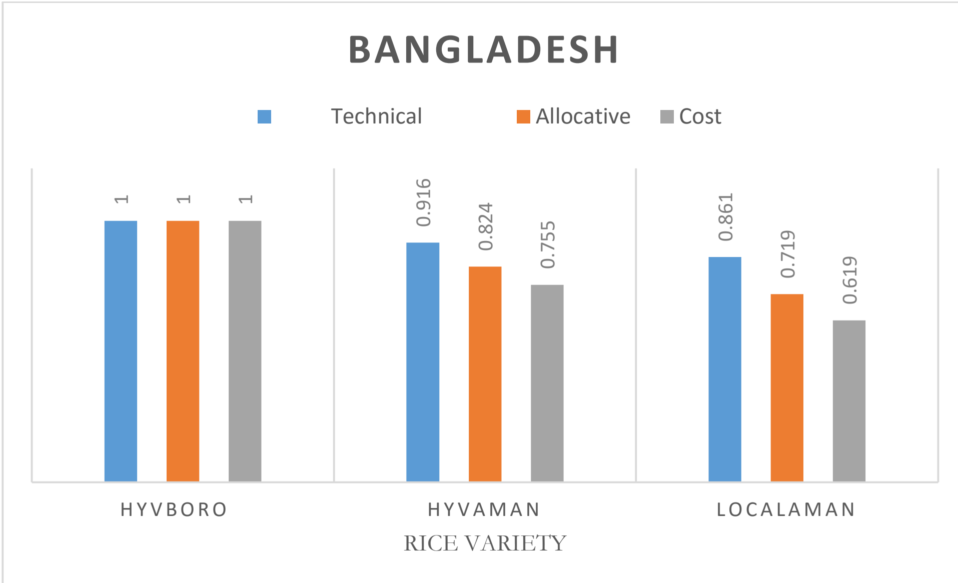
Table 2.8. Total cost of input use of HYV Boro ($/division)

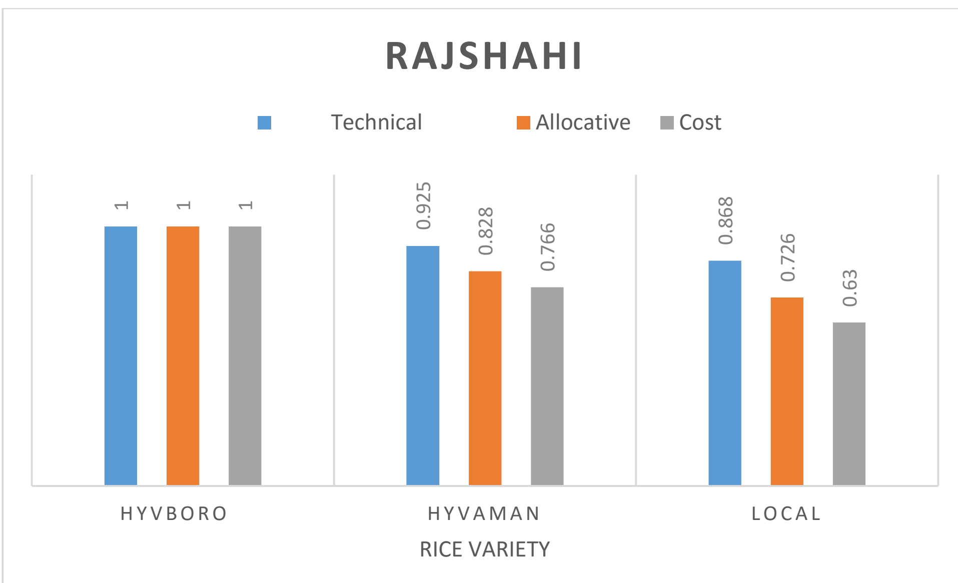
| | Seed | fertilizer | labor |
|---|---|---|---|
| Barisal | 1,591,450.155 | 4,328,728.334 | 9,023,043.778 |
| Chittagong | 4,127,124.461 | 7,757,343.616 | 12,126,044.183 |
| Dhaka | 5,835,124.192 | 13,923,653.924 | 21,904,143.664 |
| Khulna | 2,401,685.553 | 7,977,460.696 | 12,166,287.510 |
| Rajshahi | 6,223,912.318 | 17,488,173.301 | 19,625,266.294 |
| Rangpur | 1,378,774.379 | 6,179,426.058 | 7,292,615.348 |
| Sylhet | 1,290,088.908 | 4,471,108.804 | 5,203,782.524 |

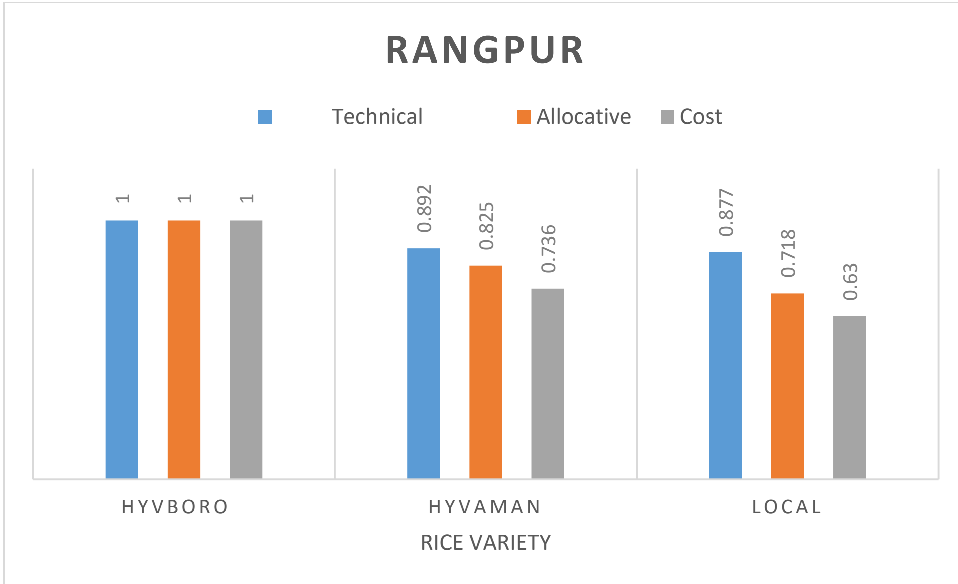
Table 2.9. Total input use per division of HYV Boro

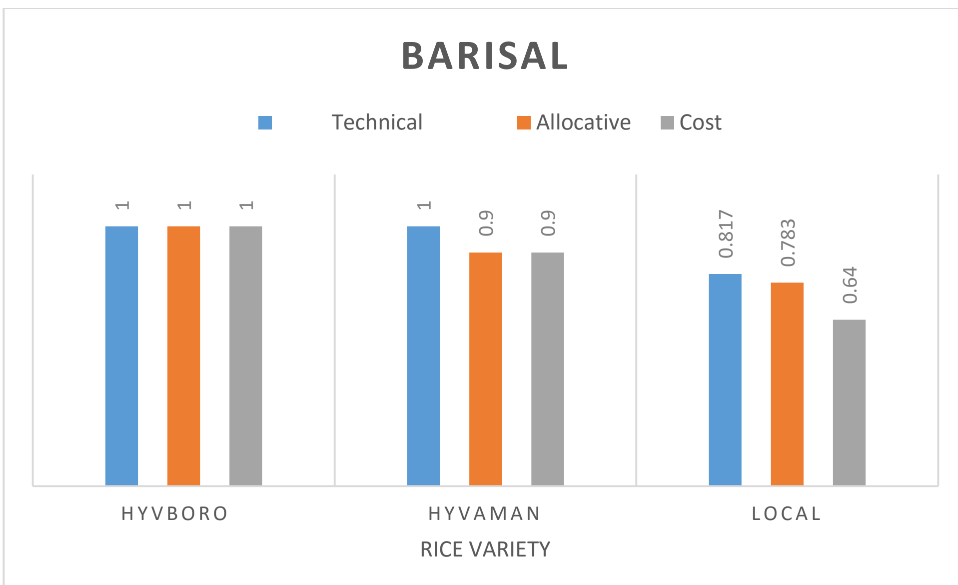
| | Seed(kg) | Fertilizer(kg) | Labor(hours) |
|---|---|---|---|
| Barisal | 8,940.596 | 182,994.648 | 432,913.052 |
| Chittagong | 13,292.67 | 272,072.099 | 643,644.852 |
| Dhaka | 21,444.01 | 438,912.466 | 103,8341.491 |
| Khulna | 11,736.53 | 240,221.351 | 568,295.082 |
| Rajshahi | 20,619.61 | 422,038.764 | 998,423.133 |
| Rangpur | 81,32.172 | 166,447.955 | 393,768.305 |
| Sylhet | 6,895.57 | 141,137.402 | 333,890.767 |

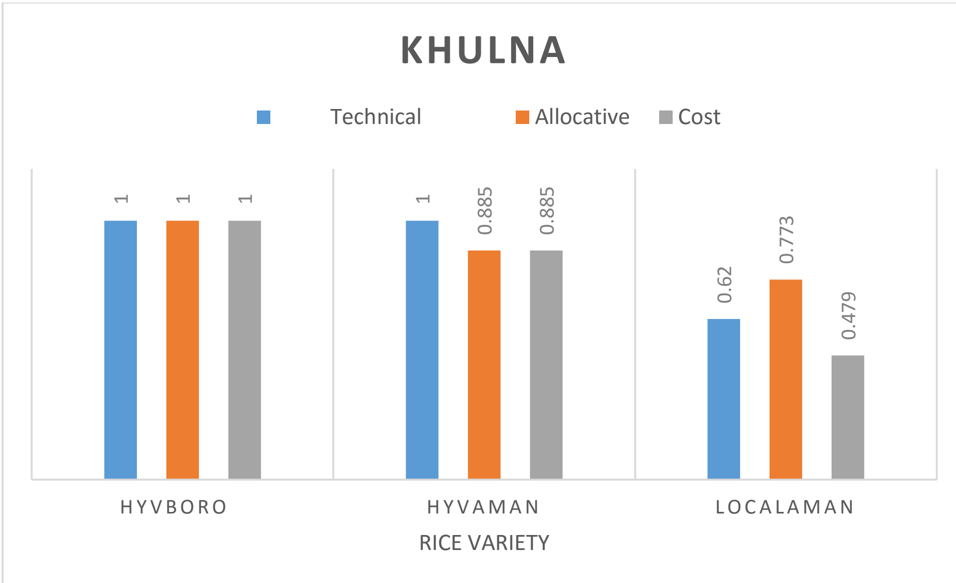
# APPENDIX 3

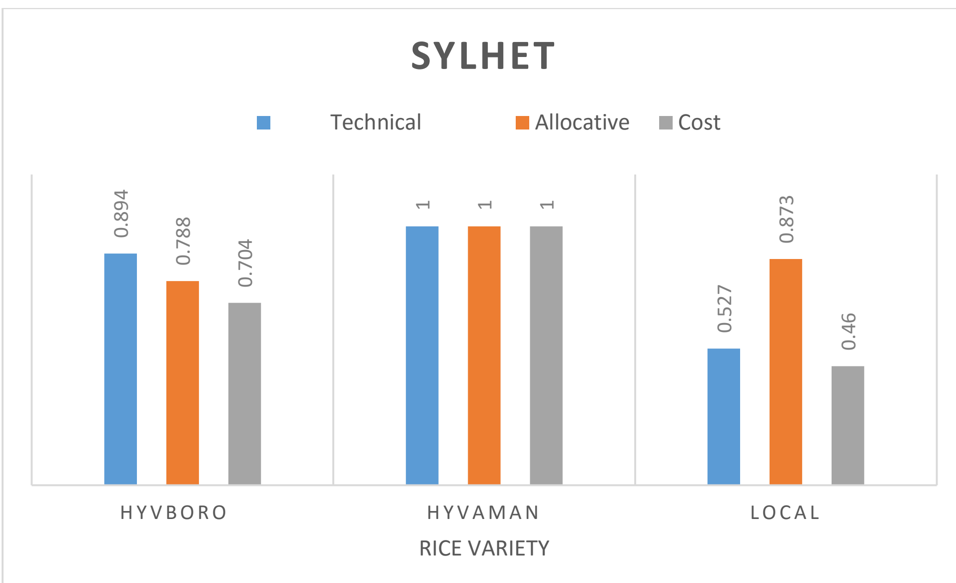

BANGLADESH
Technical
Allocative
Cost
1
1
1
0.916
0.824
0.755
0.861
0.719
0.619
HYVBORO
HYVAMAN
LOCALAMAN
RICE VARIETY

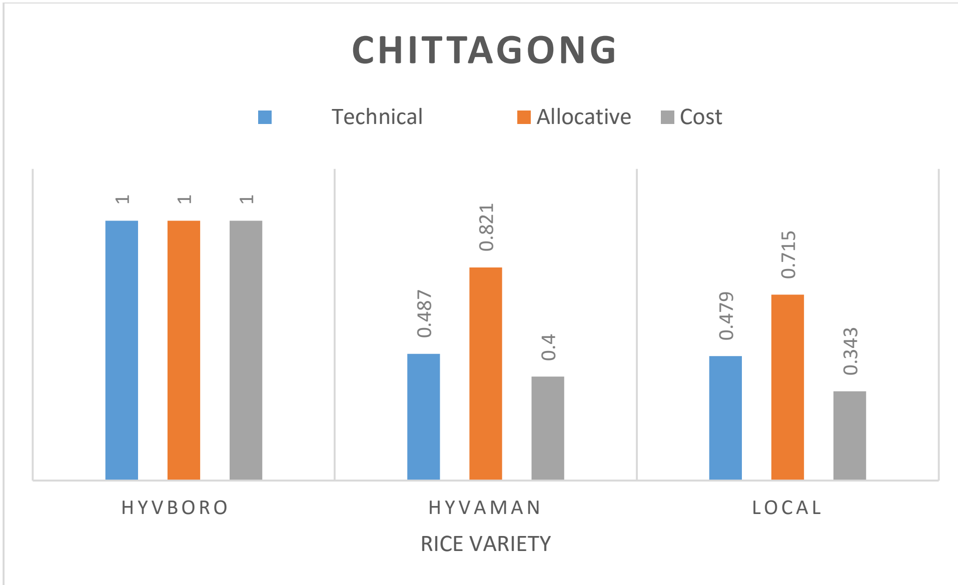

RAJSHAHI
Technical
Allocative
Cost
1
1
1
0.925
0.828
0.766
0.868
0.726
0.63
HYVBORO
HYVAMAN
LOCAL
RICE VARIETY


RANGPUR
Technical
Allocative
Cost
1
1
1
0.892
0.825
0.736
0.877
0.718
0.63
HYVBORO
HYVAMAN
LOCAL
RICE VARIETY


BARISAL
Technical
Allocative
Cost
1
1
1
1
0.9
0.9
0.817
0.783
0.64
HYVBORO
HYVAMAN
LOCAL
RICE VARIETY


KHULNA
Technical
Allocative
Cost
1
1
1
1
0.885
0.885
0.62
0.773
0.479
HYVBORO
HYVAMAN
LOCALAMAN
RICE VARIETY


SYLHET
Technical
Allocative
Cost
0.894
0.788
0.704
1
1
1
0.527
0.873
0.46
HYVBORO
HYVAMAN
LOCAL
RICE VARIETY


CHITTAGONG
Technical
Allocative
Cost
1
1
1
0.487
0.821
0.4
0.479
0.715
0.343
HYVBORO
HYVAMAN
LOCAL
RICE VARIETY