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Total Factor Productivity and the Efficiency of Rice Farms in Bangladesh: a Farm Level Panel Data Comparison of the Pre- and Post-Market Reform Period

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Abstract

The market reform policy in agriculture and the trade liberalization during the early 1990s has led to structural changes in the agricultural sector of Bangladesh. The question of whether market reform policies in Bangladesh facilitated rice production is examined in this paper. This paper uses stochastic frontier production function to measure total factor productivity (TFP), technical change, and technical efficiency change covering the period of pre-market reform (1987) and post-market reform (2000 and 2004). To fulfill the objective, the study used panel data of 73 same farm households from a field survey of 1987–1988, 1999-2000 and 2003-04. It is evident from the study results that over time period (1987-2004), the TFP increased (31.76%) only due to upward shift in the technology. Technological change increased 59.99% in post reform period. However, although TFP increased substantial inefficiencies remain in Bangladesh rice sector. Technical efficiency change (-34.46%) developed negatively over the years of study at farm level. Market reform policy has negative impact on technical efficiency change but positive in technical change and TFP change although all are declining over the time period. Therefore, government policies need for further reform of domestic market and trade policies focusing on institutional changes, tariff and nontariff barriers in order to develop a competitive environment in rice sector.

1. Introduction

As an agricultural country, the government of Bangladesh has over time undertaken different direct and indirect policy interventions for the development of agricultural sector. After independence (1971) agricultural policies were mainly state oriented but until 1980s the policies did not work at all and have observed very low growth of technological changes (Selim, 2007). To overcome the stagnant situation the government shifted all its policies gradually from state oriented to market oriented. A summary of these polices in pre-reform (1977-1989) and post-reform (1990-2004) periods is given in Table 1. Although market reform policies started in 1980s but it became momentum in 1990s, therefore, in this study we consider 1987 as pre reform period and 2000 and 2004 as post reform period. The aim of the policy reforms was to increase the production growth by reducing subsidies, reorganizing the public food distribution system and realigning market incentives. All of the policy tools were synchronized with the freeing up of the domestic markets, allowing importation of inputs and output via private channel. The government reduced the control in agricultural input and output markets and lowered tariffs and non-tariff barriers (NBTs), gradual eliminated subsidies on fertilizer and minor irrigation equipment, minimized government involvement in input distribution, allowed private sector in distribution of agricultural inputs. However, although various polices have been taken gradually (after 1990s to till date) with the aim of ensuring food grain availability and long-term food security, this is still out of reach and the country is still identified as a food deficit country with occasional self-sufficiency in one or two years.

As a densely populated country in the world, Bangladesh need to support new mouth of two million peoples every year along with her population of 132 million (BBS, 2009). Although overall rice production steadily increased over the years, this is not yet sufficient to meet the demand of the growing population every year. To meet the emergent demand for food, the production growth of rice must depend on improvements in technology and farms efficiency.

Table 1: Summarization of market reform policies in Bangladesh during 1977-2004

Period	Policy	Purpose	Observed outcome
Pre-reform (1977-1989)	• Huge input subsidy • Market quantity rationing • Differentiated tariffs rates • Input distribution through government channel • Credit ceiling • Price control • Output price support	• Self sufficiency in food production • Protecting domestic farmers from competition • High production growth • Reducing production cost of the farmers	• Low output growth • Slow rate of technology adoption
Post-reform (1990-2004)	• Deregulation of input subsidy • Reducing government control in agricultural input & output markets • Lowering tariffs and non-tariff barriers (NBTs) • Food grain importation by private sector • Gradual elimination the public food grain distribution system • Price stabilization through open tender procurement policy • Permitting the private sector in the procurement of fertilizers and irrigation equipment	• High production growth • Increase productivity & efficiency of farm • Occasionally ensuring food security • Agricultural inputs availability to farmers	• Boro Rice production increased • Less than projected growth in production of hybrids crops

Sources: Compiled from Selim (2007) and Salim and Hossain (2006)

Studies on total factor productivity (TFP) growth in Bangladesh are limited to the work of Pray and Ahmed (1991), Dey and Evenson (1991) and Coelli *et al.,* (2003). However, so far, no studies pointed out the TFP of rice farmers in Bangladesh using farm level panel data. To fill up this gap we used farm level panel data to estimate changes of TFP, efficiency and technical change and also we focus only to the rice instead of total foodgrain or agricultural production as aggregate. Since the major policy changes in relation to agriculture in general and to the rice sector in particular, have been introduced in the early 1990s, the main objective of this study is to find out the trend of productivity and efficiency at farm level. To fulfill this objective, the study intends to estimate total factor productivity (TFP), technological progress and technical efficiency changes covering the data from three different periods; the pre-reform (1987) and the post-reform (2000 and 2004), using translog stochastic frontier production function.

The remainders of the paper are as follows. The next section of this paper outline the econometric model used to derive the TFP index. Section 3 describes the data, the sampling procedures and the derivation of farm level panel data used for the analysis from a nationally representative data set. The hypotheses tests and model estimation are described in section 4. The results and discussions are given in section 5 followed by a summary and conclusions at the end.

2. Econometric model

There are two competing approaches to measure efficiency, the non-parametric data envelopment analysis (DEA) and the parametric stochastic frontier model (SFA). The framework for the non-parametric method, DEA was initiated by Farrell (1957) and re-formulated as a mathematical programming problem by Charnes *et al*., (1978). The stochastic frontier approach was proposed first by Aigner *et al.,* (1977), then by Meeusen and Broeck (1977). The stochastic frontier approach has contributed significantly to the econometric modeling of production and the estimation of technical efficiency of farms. This approach is a regression-based approach which assumes two unobserved error terms representing efficiency and statistical noise and allows estimation of error terms via maximum likelihood. The advantage of the stochastic frontier approach is the capability to measure the efficiency in the presence of statistical noise. Many researches (among which Ruggiero, 1999; Ondrich and Ruggiero, 2001) have explained the pros and cons of both SFA and DEA approaches. Although both approaches are both adversely affected by measurement error when applied to cross sectional data, the stochastic frontier model of panel data can more effectively handle the statistical noise than DEA. Gong and Sickles (1992) and Sickles (2005) show that, the panel data version of the stochastic frontier model works well in achieving relatively high rank correlations between estimated and true inefficiency. This is because the panel data model incorporates additional information from the times series nature of the data as well as the distributional assumptions which allow estimation via maximum likelihood and incorporation of either random or fixed effects. Panel data stochastic frontier model maintain the advantage over DEA, which typically relies on cross-sectional data to estimate efficiency. In this study we use a panel dataset, therefore, we choose stochastic frontier production function with a simple exponential specification of time-varying farm effects which incorporates balanced panel data associated with observations on a sample of 73 farms over T (1987, 2000 and 2004) periods to estimate efficiency and total factor productivity.

The stochastic frontier production function for panel data can be written as:

$$Y_{it} = \exp(X_{nit}\beta + V_{it} - U_{it}) \qquad (1)$$

where the dependent variable Y_{it} represent the total rice produced (kg/farm) by the i_{th} farm in the t_{th} year (here, t =1, 2 in which 1 is for the year 1987 and 2 is for the year 2000), X_{nit} denotes n_{th} input variables, t is a time trend which represents technological change, β is the associate vector of unknown parameters to be estimated; the statistical noise V_{it} are the error component which are assumed to be i. i. d (identically and independently distributed) with $\{N(0, \sigma_v^2)\}$. They are also assumed to be uncorrelated with the regressors. The other error components U_{it} ,s are non-negative random variables, associated with technical inefficiency in production, which are assumed to i. i. d with mean, μ and variance, σ_u^2, as well as truncated at zero. Since U_{it} is a non-negative random variable, these technical efficiency predictions are between zero and one, where the value of 1 indicates full technical efficiency and value of zero full technical inefficiency.

To calculate the TFP index between period s (the base period) and period t (present period) we need to measure technical efficiency and technological change. This TFP index is equivalent to the decomposition of the Malmquist index suggested by Fare *et al.*, (1985). The technical efficiency of production for the i_{th} farm at t_{th} year can be calculated using equation (2) as follows (Coelli *et. al.*, 1998):

$$TE_{it} = E\left[\exp(-U_{it})/(V_{it} - U_{it})\right] \qquad (2)$$

Technical efficiency change (EC_{it}) is then calculated as:

$$EC_{it} = \frac{TE_{it}}{TE_{is}} \qquad (3)$$

Where, $TE_{it} = d_0^{1}(X_{it}/Y_{it})$ and $TE_{is} = d_0^{s}(X_{is}/Y_{is})$

Here, the notation $d_0^{1}(X_{it}/Y_{it})$ represents t period observation and $TE_{is} = d_0^{s}(X_{is}/Y_{is})$ represents s period observation. The index of technological change (TC_{it}) can be directly calculated between two adjacent period s and t from the estimated parameters of the stochastic production frontier model. The partial derivatives of the production function are evaluated with respect to time at X_{it} and X_{is}. We then convert these into indices and calculate their geometric mean. Following Coelli *et al.*, (1998), the calculation of the technical change index is as follows in equation (4):

$$TC_{it} = \left\{ \left[1 + \frac{\delta f(X_{is}, s, \beta)}{\delta S} \right] X \left[1 + \frac{\delta f(X_{is}, s, \beta)}{\delta S} \right] \right\}^{0.5} \qquad (4)$$

The indices of technical efficiency change (EC_{it}) and technical change (TC_{it}) obtained by using equations (3) and (4) respectively can be multiplied with each other to obtain a TFP index as follows in equation (5)

$$TFP_{it} = EC_{it} * TC_{it} \qquad (5)$$

3. Data and sampling

The data for the analysis are drawn from a longitudinal survey of 1,239 households, beginning in 1987-88 with the support of the Bangladesh Institute of Development Studies (BIDS) for the research study the impact of technological progress on income distribution and poverty in Bangladesh (Hossain *et al.*, 1994, David and Otsuka, 1995). In field survey at first 64 unions (small administrative unit) were randomly selected from a list of all unions in the country, then one village was selected from each union that represent the union best with regard to literacy rate and the land holding size. A census of all the households in the selected villages was conducted to stratify the households by the size of land ownership and land tenure. A random sample of 20 households was drawn from each village such that each stratum is represented by its probability proportion. A repeat survey were also conducted by the International Rice Research Institute (IRRI) to the same villages in 2000-2001 for a study of the impact of rice research on poverty reduction in Bangladesh sponsored by the International Food Policy Research Institute (IFPRI). A sample of 30 to 31 households from each of the 62 villages (1880 households) was drawn using the stratified random sampling method. The stratification was based on a wealth ranking technique of the participatory rural appraisal (PRA) method. Again a repeat survey was conducted in 2004-05 by the International Rice Research Institute (IRRI) covering the households present in the first two surveys in 1987-88 and 2000-01. The sample size of households rose to 1,927 in the last survey 2004-05. The sample of these surveys is nationally representative as shown by the comparison of the estimates of variable for which data are available from official statistics (Hossain *et al.*, 1994, Rahman and Hossain, 1995).

However, keeping in mind the objective of our study, we used farm level panel data, therefore selected three sets (from 1987-88, 2000-01 and 2004-05 survey) of data and same 73 farm households were selected from each set. This panel data study at farm level will allow us to examine technical efficiency change (TEC), technical change (TC) and the total factor productivity change (TFP) over a 17 years spell since 1987-1988 which cover the period of pre-reform and the post-reform period. The first panel offers a wide window of thirteen years (1987-2000) allowing us to examine long-run TEC,TC and TFP change, while the second panel permits understanding of short-run TEC,TC and TFP change over the four year(2000-2004) spell.

The variables used in this study are given below

1. Output of rice: includes all seasons and varieties of rice (in kg)
2. Inputs:
    a. Land (total rice cultivated land, in decimal)
    b. Seed (total amount of seed (in kg) used for rice cultivation)
    c. Labour
        i. Family labour (total man-days for rice cultivation)
        ii. Hired labour (total man-days for rice cultivation)
    d. Fertilizer (total amount of fertilizers (urea, phosphate, potash, and gypsum) used in kg for rice cultivation)
    e. Pesticide(total value of pesticide at1996 prices)

Table 2 presents the definitions, units of measurement, and summary statistics for all the variables used in this study.

Table 2: Definition, measurement and summary statistics of variables

Variables	Measure	Mean			Standard deviation			Minimum			Maximum		
		1987	2000	2004	1987	2000	2004	1987	2000	2004	1987	2000	2004
Rice output	Kg per farm	5211.44	3919.32	1893.49	4356.56	4554.18	2526.60	281.25	133.97	262.5	20625	22162.5	15000
Land cultivated	Decimal	251.30	70.87	78.65	199.94	60.81	55.59	10	10	13	1006	300	320
Fertilizers	Kg of active nutrients(N, P, and K) per farm	327.87	69.92	78.91	539.84	71.64	57.24	10	0	4.67	4120	390	308
Labour	Man-days per farm	194.53	35.63	32.8	143.06	28.15	21.18	12	5	9	699	159.67	141
Seed	Kg per farm	126.78	56.69	33.75	125.93	59.55	48.94	10	3	6	750	250	360
Pesticides	Taka (in 1996 price)	160.64	122.87	142.19	319.46	178.86	373.62	0	0	0	1600	840	3100

Sources: Sample survey, 1987-88, 2000-2001 and 2004-05; Note: N, P and K stands for Nitrogen, Potash and Phosphate

4. Model estimation and hypotheses tests

First, the functional form of the stochastic frontier production function was determined by testing the adequacy of the Cobb–Douglas function relative to the less restrictive Translog function. The Cobb-Douglas and the Translog production frontier models are defined below as equations (7) and (8)

$$\ln Y_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n \ln X_{nit} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + V_{it} - U_{it} \qquad (7)$$

Where, i=1, 2……, I and t=1, 2, ……, T,

and $$\ln Y_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n \ln X_{nit} + \frac{1}{2}\sum_{n=1}^{N} \sum_{j=1}^{N} \beta_{nj} \ln X_{nit} \ln X_{nit} + \sum_{n=1}^{N} \beta_{tn} t \ln X_{nit} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + V_{it} - U_{it}$$

where, lnY is the log of rice output, and the five independent variables ($\ln X_i$) are the log of land, seed, fertilizer, labour, pesticides and the time trend. The variables defined for estimation are mean differenced to allow direct estimation of the output elasticities. In this model the time trend (t) is interacted with the inputs (land, labour, fertilizer, seed and pesticides) which allows for non-neutral technical change. We also include time squared variable in this model which allow for non-monotonic technological change. This model also incorporates a simple exponential specification of the time-varying inefficiencies, following Coelli and Battese (1996).

The maximum-likelihood estimates (MLE) of the parameters in the Cobb–Douglas and in Translog stochastic frontier production function defined by equations (7) and (8), given the specification defined from equation (1), are obtained by using FRONTIER 4.1 (Coelli, 1994). A series of formal hypothesis tests were conducted to determine the preferred functional form and the distribution of the random variables associated with the existence of technical inefficiency and the residual error term. The results of the hypotheses tests using likelihood ratio (LR) are presented in Table 3.

Table 3: Hypotheses tests

Null Hypothesis	Stochastic frontier model
Choice of functional form – Cobb–Douglas vs translog model ($H_0 : \beta_{jk} = 0$) for all *jk* Likelihood ratio test statistic (χ^2)	83.61
Degrees of freedom	21

p-value (Prob. > χ^2)	0.00
Decision	rejected
Production structure exhibits constant returns to scale ($H_0 : \sum \beta_j = 1$ for all *j*)	1.69
Likelihood ratio test statistic (χ^2)	
Degrees of freedom	1
p-value (Prob > χ^2)	0.1939
Decision	accepted
No inefficiencies present in the model a ($H_0 : \mu = \gamma = 0$)	16.53
Likelihood ratio test statistic (χ^2)	
Degrees of freedom	5
p-value (Prob. > χ^2)	0.000
Decision	rejected
No technical change over time ($H_0 : \beta_5 = \beta_{5i} = ... = 0$)	32.63
Likelihood ratio test statistic (χ^2)	
Degrees of freedom	6
p-value (Prob > χ^2)	0.000
Decision	rejected
Technical inefficiency of the farm are time invariant ($H_0 : \eta = 0$) Likelihood ratio test statistic (χ^2)	4.24
Degrees of freedom	1
p-value (Prob > χ^2)	0.000
Decision	rejected

A test of hypothesis on the choice of functional form (Cobb–Douglas versus Translog) confirms that the choice of Translog production function is a better representation of the production. The null hypothesis that the Cobb–Douglas production function is an adequate representation for the rice data ($H_0 : \beta_{jk} = 0$) (for all *jk*) is strongly rejected.

The parameter γ is the ratio of the error variances that is $\gamma = \sigma_u^{\ 2} / (\sigma_v^{\ 2} + \sigma_u^{\ 2})$. The value of γ vary between zero and one, if the value of γ=0 it means that technical inefficiency is not present, and if γ =1 it means that there is no random noise. The test of significance of the inefficiencies in the model rejected the null hypothesis ($H_0 : \mu = \gamma = 0$), indicating that it is a significant improvement over an OLS specification. The null hypothesis, that there is no technical change over time ($H_0 : \beta_5 = \beta_{51} = \beta_{55} = 0$) is also strongly rejected, indicating that technological change exists in the rice farm. Finally, the hypothesis that technical inefficiency of the farm is time invariant ($H_0 : \eta = 0$) is rejected, indicating that technical efficiency levels vary significantly over time.

5. Results and discussions

The parameter estimates from the translog stochastic frontier production function are reported in Table 4. The maximum-likelihood estimates (MLE) of translog stochastic frontier production function were estimated using FRONTIER 4.1 (Coelli, 1996).

Table 4: Maximum likelihood estimates of the stochastic production frontier model

Name of the variables	Parameters	Translog model	
		Coefficients	t-ratios
Production function			
constant	a	0.1608	0.88
land(decimal)	x_1	0.2700***	3.09
labour(man-day)	x_2	0.0397	0.46
Fertilizer(kg)	x_3	0.0910*	1.75
seed(kg)	x_4	0.6071***	14.16
pesticides	x_5	0.0430***	3.30
time	t	0.3285**	2.68
land^2	x_{11}	0.0887	0.24
labour^2	x_{22}	-0.1533	-0.46
fertilizer^2	x_{33}	-0.0080	-0.19
seed^2	x_{44}	0.1730***	2.55
pesticides^2	x_{55}	0.0088***	3.03
land*labour	x_1x_2	0.4206	1.35
land*fertilizer	x_1x_3	-0.1460	-1.33
land*seed	x_1x_4	-0.2837**	-2.43
land*pesticide	x_1x_5	-0.0140	-0.91
labour*fertilizer	x_2x_3	0.0379	0.36
labour*seed	x_2x_4	-0.1587	-1.36
labour*pesticides	x_2x_5	0.0220	1.58
fertilizer*seed	x_3x_4	0.1046*	1.86
fertilizer*pesticide	x_3x_5	-0.0082	-1.36

seed*pesticide	x_4x_5	-0.0227***	-3.59
time*land	tx_1	-0.1216	-0.73
time*labour	tx_2	-0.1346	-0.75
time*fertilizer	tx_3	0.1157	1.16
time*seed	tx_4	0.2129**	2.40
time*pesticide	tx_5	-0.0151	-1.54
time*time	tt	-0.5228**	-2.62
diagnosis statistics			
σ2		0.1727***	7.98
γ		0.4294***	3.92
μ		0.5266*	1.85
η		-0.5412**	-2.49
log likelihood		-84.62	
number of observation		219	219

Notes: * significant at 10% level ($p < 0.10$), ** significant at 5% level ($p < 0.05$), *** significant at 1% level ($p < 0.01$)

From the Table 4 it is evident that all basic inputs except labour significantly influence rice production. Out of all five inputs, seed and land appear to be the major determinants of rice production growth. The estimated coefficients of land, fertilizer, seed, pesticides and time are significantly different from zero.

An advantages of the Cobb–Douglas production function is that the coefficients are themselves output elasticities (except for the time variable), but for the translog the elasticities are functions of the estimated coefficients and the values of the input variables. However, when the mean-differenced variables (that is, $X_i^* = X_i - \overline{X}$) are used in the estimation of the translog function, the output elasticities are again simply the coefficients on the first order terms. In this study we used mean differenced variables to get the elasticities directly from the estimated translog production frontier model.

Seed remains the single most important input with an output elasticity of 0.60 followed by land at 0.27 and fertilizer at 0.09, pesticides and labour at 0.04, respectively. Output elasticity of seed is estimated at 0.60 indicating that a 1% increase in seed use will increase output by 0.60%. Similarly, output elasticity of fertilizer is estimated at 0.09 indicating that a 1% increase in fertilizer use will increase output by 0.09%. The elasticity of output for seed, among all the output elasticities, is the highest which shows that seed as an input has major influence on output followed by land. The elasticity associated with seed is the largest one. The result is not surprising at all, the result is also same line with Hossain *et. al.*, 2006 study.

From the study Hossain *et al.*, 2006, it is evident that the expansion was relatively slow during the 1970s, but by the rapid expansion of MVs seed took place after the market reform policies. However, by 2001–02, the coverage of MV reached 65% of rice-cropped area.

It is reasonably that for a labour surplus economy, labour has the lowest output elasticity which is however not statistically significant. The sum of elasticities is equal to 1.03 (0.27+0.03+0.09+0.60+0.04) suggesting constant returns to scale at the sample mean data point. The null hypothesis with regard to the constant return to scale was tested and accepted (Table 3). The coefficient on the time-trend variable is positive (0.32) and statistically significant, which indicates that there is positive technological change over the period of 17 years (1987 to 2004) that has contributed to output significantly. In that case, the frontier is shifted upwards and the effect is non-linear, as time squared coefficient is also statistically significant at 5% level.

The value of γ is 0.42 and is highly statistically significant, implying that 42% of the variation in the composite error term is due to the inefficiency component (Table 4). This implies that there is a potential for further increase in rice production (output) without increasing inputs by simply improving the production efficiency at the farm level. However, this simple test statistics also supports our results of LR test in Table 3.

The significant negative coefficient on η (the time-varying efficiency effect) indicates that technical efficiency declined over time (17 years). The value of η is -0.54 and is statistically significant (Table 4). However, Coelli *et al.,* (2003) also found similar result in Bangladesh study and estimated that the technical efficiency declined throughout the time at the rate of 0.21 per cent per annum.

After getting the result in table 4, a relevant research question then arises what are the farm specific efficiency score? The farm specific efficiency scores are presented in Table 5. It is evident from the Table that mean efficiency level declined over time, in 1987 it was 83%, in 2000 it stands for 73% and in 2004 it became 60%. The estimated mean efficiency level over time indicating that rice production can be increased by improving technical efficiency alone with no additional use of resources. The estimates of 1987 and 2000 are slightly lower than those reported by Rahman (2003) and Wadud and white (2000) on Bangladesh rice production. However, research study of technical efficiency estimates in 2004 (mean efficiency 60%) on rice production in Bangladesh is not available to compare our estimated efficiency level. However, Coelli *et al.* (2002) reported technical efficiency of Aman rice was 66 per cent and for Boro rice technical efficiency was 69 per cent in Bangladesh.

Table 5: Technical efficiency over time (1987 to 2004) in rice production

Variable	**1987**	**2000**	**2004**
Efficiency score			
Up to 70%	0	30	61
71-80%	19	29	10
81-90%	49	14	2
91-100%	0	0	0
Mean efficiency level	0.83	0.74	0.60
Standard deviation	0.05	0.07	0.10
Maximum	0.93	0.88	0.81
Minimum	0.72	0.58	0.39

This study also measured total factor productivity (TFP) and its decomposition. Percentage change measures of technical efficiency change (TEC), technical change (TC), and total factor productivity (TFP) change were also calculated for each farm using stochastic frontier approach.

Table 6: Cumulative percentage change measure of technical efficiency change, technical change and TFP change

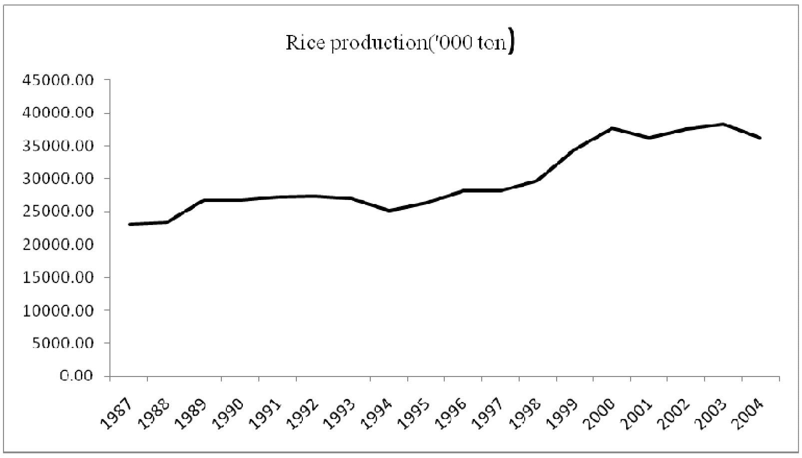
Year	Efficiency Change	Technical Change	Total Productivity Change
1987	0	0	0
2000	-12.84	66.68	255.61
2004	-34.46	59.99	37.17

Source: Own estimation

The indices for changes in total factor productivity, technical efficiency and technological change for the period of 1987 to 2000 and 2004 are presented in Table 6. Technological change was positive from 1987 to 2000 and 2004, whereas persistent negative in technical efficiency change from 1987 to 2000 and 2004. As technical change is found positive means that the improvement of technology over time. However, TFP change was also positive from 1987 to 2000 and 2004 but declining from 1987-2000 to 1987-2004. This positive but declining TFP change result came from the opposing effects of efficiency (declines) and technological progress (positive). .

Our estimate of time trend is 0.3285 (see Table 4) that means that the average annual TFP change is 0.33%. This is significantly less than the value of 37.17/17= 2.18% which is directly obtained from Table 6. This illustrates the effect of finishing year in the analysis; the results can be influenced by whether the computing year is a good or a bad season. The trend of rice production is presented in a figure 1. From the figure it is evident that from 1987 to

2000, production was not stable, some year we observed good production some bad production which influence our TFP change result. However, in our analysis, the year 2000 the country observed a bumper production and in 2004 production declined compare to 2000.



Source: FAOStat, 2008

Figure 1: Rice production ('000 MT) over the year 1987-2004

It is evident from our results, that over the 17 years (1987-2004) period, the TFP is positive only due to upward shift in the technology. Technical efficiency is negative over the observed years at farm level in Bangladesh.

The indices of technical efficiency, technical change and TFP are separately regressed on the seven explanatory variables. These are the age, education, Household size (family members) farm size, Effective protection coefficient (EPC) change, owned land and off farm work. The OLS estimates of these explanatory variables on three indices are reported in Table 7. Most of the explanatory variable confirms the expectations in terms of the direction of the effects.

The contribution of the Effective protection coefficient (EPC) change to efficiency has the expected positive impact and is significant in model 2 and model 3. Also the level of influence of this variable is highest, exposing its dominant influence on rice production in Bangladesh. However, EPC change to efficiency has negative impact and significant in model 1. As we used EPC change as market reform policy so this result is not surprising. Market reform policy has mixed fortune. The classical economists argue that free trade is an engine of growth while protections lead to miss use of resources, hence adversely affects economic development. On the contrary, the critics argue that openness has its costs and sometimes it could be detrimental to economic development (Rodriguez and Rodrik, 1999; Chang *et al.*, 2005). However, a relevant study Salim and Hossain, 2006 found effective rate of assistance (ERA) to efficiency has negative impact and significant. Such an outcome might be the result of the failure of liberalization to remove anti-agriculture bias policies such as tariffs, NTBs, and differential assistance to farmers and the anti-agriculture bias of the relevant government policies largely contributed to the reduction of farm level efficiency and thereby slow down of the overall agricultural growth.

Farm size and household size variable has correct signs in all three models and both are significant in the technical efficiency change model and only household size is significant in technical change model.

The coefficient of age (year) is negative in explaining technical efficiency implies that older farmers are technically less efficient than younger farmers. This could be explained in terms of the adoption of new technology. Older farmers are likely to be more conservative and less receptive to new technologies and practices than younger farmers. Age variable has also correct signs in technical efficiency change and technological change model and significant. However, education has incorrect sign in technical efficiency model and but correct sign in technical change model and TFP change model. However, the variable is significant in model 1 and model 2.

Education (years of schooling) is used as a proxy for managerial input. Higher level of education may lead to better assessment of farming issues and better farming decisions. However, overall the educational level of the people engaged in agricultural farming in Bangladesh is very low because agriculture is less rewarding for higher educated people therefore it is unlikely that education peoples remain in agricultural farming as profession. Education variable has negative impact in model 1 and significant and in model 2 it is significant but positive sign. The negative sign of education is not unexpected since the negative influence of education on technical efficiency is also reported by Coelli *at al.*, (2003), Deb (1995), Hossain (1989), Rahman and Shankar (1999).

Opportunities for off farm work (dummy variable, if farm has off-farm income then 1, otherwise 0) that means access to non-agricultural income reduces technical efficiency as expected. Off farm work has negative impact on all three model and significant in model 1 and model 2, whereas owned land has negative impact on model 1 and model 3 but positive impact on model 2 and significant only in model 1.

Thus from the three models we found only EPC change has significant impact in all three model but the impact is positive in technical change model and TFP change model but negative in efficiency change model. Others farm specific variables are positive in two models and negative in other, similarly significant in one or two model and insignificant in other.

Table 7: Factors affecting changed in technical efficiency, technical change and total factor productivity in rice farms

Regressors	Dependent Variables					
	Model1		Model2		Model3	
	Technical efficiency index	Expected sign	Technical change index	Expected sign	TFP index	Expected sign
Constant	-1.5802		2.4667		-329.42	
	(-0.63)		(0.47)		(1.44)	
Age	-0.1640***	√	-0.3485***	√	0.3914	x
	(-3.41)		(-3.50)		(0.09)	
Education	-0.2887***	x	0.3898*	√	12.40	√
	(-2.65)		(1.73)		(1.26)	
Household size	0.5236***	√	1.0340***	√	6.28	√
	(2.68)		(2.56)		(0.35)	
Farm size	0.0110***	√	0.0045	√	0.3828	√
	(3.44)		(0.49)		(1.32)	
EPC	-5.7596***	x	58.04***	√	286.12***	√
	(-5.25)		(25.59)		(2.88)	
Owned land	-0.0039*	√	0.0019	x	-0.1434	√
	(-1.69)		(0.40)		(-0.74)	
Off farm work	-3.9079***	√	-7.64***	√	-43.31	√
	(-3.02)		(-2.86)		(-0.37)	
Adjusted R^2	0.29		0.76		0.03	
F(7, 211) statistics	13.68		100.93		2.53	

Notes: 1) * Significant at 10% level ($p < 0.10$); ** Significant at 5% level ($p < 0.05$); *** Significant at 1% level ($p < 0.01$); 2) The values in the parentheses indicates t-ratio

6. Conclusions and policy implications

The aim of the policy reforms in the Bangladesh agricultural sector was to increase the production growth by reducing subsidies, reorganizing the public food distribution system and realigning market incentives. All of the policy tools were synchronized with the freeing up of the domestic markets, allowing importation of inputs and output via private channel. The question of whether market reform policies in Bangladesh enhanced the productivity and efficiency is examined in this paper. The analysis does not confirm the direct causality, the direct impact of polices to rice productivity and production efficiency rather it explains what has happened during the period of pre and post-reforms. The study uses a stochastic frontier production function model to measure the technical efficiency change, technical change and total factor productivity (TFP) change and using farm level panel data.

It is evident from the results of the study that over this 17 years period (1987-2004), the TFP is increased significantly from 1987-2000 and 1987-2004 only due to upward shifting of the technology, however, TFP declined from 2000 to 2004 but still positive. However, it can be argued that the TFP growth may partly be attributable to market deregulation policy and partly to other factors such as good weather, infrastructural development, information, green revolution, extension & research expenditure etc. In this study we used effective protection coefficient change as a proxy of market reform policy. It is not unlikely that the reform policies removed various distortions from agricultural input and output markets and therefore enhanced farmers' accessibility to new high yielding seed varieties, modern technology, market information, which all might contributed to improved TFP.

However, although TFP increased, still substantial inefficiencies are present in Bangladesh rice production. Our study shows that technical efficiency changes are negative over the observed years at farm level. Our results are in line with other studies. For example Coelli (2003) shows that technical efficiency declined over time (1960-61 to 1991-92), Sharif and Dar (1996) indicated relatively lower (81.5 per cent) technical efficiency and greater variability in efficiency of modern rice farmers. Deb (1995) found relatively lower (74 per cent) technical efficiency of rice farmers in Bangladesh. Salim and Hossain (2006) argued that although some of the farmers are producing close to the production frontier but many of the farmers are not, only 6% to 9% of sample farms are producing 86% to 100% efficiency level whereas 40 % farms are producing below 55% efficiency level. Also a recent survey conducted by the ministry of agriculture (MOA), Bangladesh, showed that there is a considerable yield gap between actual and potential output at the farm level. The potential yield of rice (modern variety) is around 6 tonnes per hectare against 2.78 tonnes of actual output (MOA, 2003). This can be explained by lower efficiency levels. In our result we found that significant percentage of the variation (42%) in the composite error term is due to the inefficiency component. This implies that there is a potential for further increase in rice production (output) without increasing inputs. Thus the results infer that there is a potential for further increase in output by simply improving the productive efficiency at the farm level.

Some factors such as age, education, family size, farm size, land ownership, access of off farm work and market reform policy are the reasons explaining the low farm level efficiency. Some other factors which we failed to capture in our dataset are also the reasons explaining the low farm level efficiency such as lack of capital, poor infrastructure, small and fragmentized plot size, inadequate researches, insufficient extension services, lack of training etc. We therefore, recommend to paying more attention to these factors to stimulate increased productivity and for improving the farmers' efficiency level. Only by taking on board these factors hampering farm level efficiency improvements, the old Bangladesh dream of self-sufficiency might come true.

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