A Novel Approach to Verifying Evaluation of Agricultural Products with Productive Efficiency: An Empirical Study

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ABSTRACT

The parametric approach to productive efficiency involving stochastic frontier analysis is widely used in evaluating different projects and programmes of many sectors in an economy. It actually evaluates the projects or programmes in terms of performance of the production units/farms associated with the projects/programmes. However, estimation of productive efficiency is sensitive to a number of factors including specifications of the stochastic frontier model as well as the inefficiency effect model, functional form of the frontier model, manipulation of data, procedures of estimating inefficiency effect model and so on. This is why evaluation of projects by productive efficiency with stochastic frontier analysis calls for a verification to ensure if the estimates are genuine. This verification actually undertakes evaluation of the projects again adopting an alternative approach. If the outcomes from both of the approaches are the same, the evaluation is said to be genuine; in other words, the evaluation performed by a parametric approach involving productive efficiency has been authenticated. Productive efficiency estimated by nonparametric approach can be used as an alternative technique for evaluation here. But there are serious limitations with the nonparametric approach to productive efficiency in that it takes no account of statistical noise, rather translates statistical noise as inefficiency; besides, it does not provide a logical basis for statistical inference. This study, however, introduces a novel approach, the yardstick of productivity, to authenticate evaluation of projects in agriculture where the parametric approach to productive efficiency has been used. Yardstick of productivity approach involves the measures of yield-gap and cost-gap against technical efficiency and cost/economic efficiency respectively in the verification process. However, if the results of evaluation of projects from both of the approaches come up with identical conclusions, it is said that the evaluation has been authenticated.

Keywords: Parametric approach to productive efficiency, stochastic frontier analysis, yardstick of productivity approach, yield-gap, cost-gap and project evaluation.

INTRODUCTION

Productive efficiency estimated with stochastic frontier models is widely applied in evaluating projects and programmes in agriculture, education, industry, service sectors and so on. In agriculture, projects and programmes are mainly taken towards improving productivity and farm income and then promoting environmental sustainability (World Bank 2010). These projects and programmes involve huge economic importance because of their backward and forward linkages. Indeed, sustainable prosperity in an agrarian economy largely depends on successful implementation of potential projects. This is why evaluation of these projects bears utmost importance from the Governmental investment decision as well as stakeholders' welfare points of view. The primary purpose of an evaluation is to make an overall judgment about the efficiency of an implemented project, or to improve the design and performance of a future project (Global Environment Facility 2010; ADB 2007). The development community, on the other hand, emphasises the need to evaluate projects for the purposes of learning lessons for policy making as well as ensuring accountability (Winters et al 2011; Kusek and Rist 2004). Therefore, the need for authenticating evaluation of project(s) cannot be denied.

Evaluation is a systematic process of assessing projects, programmes or policies in order to obtain credible information about their performance for further actions. Among the alternative ways of evaluating agricultural projects, productive efficiency is one of the popular ways by which agricultural projects are evaluated (Kalirajan and Shand 1986; Dawson 1987 and 1990; Dawson and Lingard 1991; Sharif and Dar 1996; Seyoum et al 1998; Rahman et al 2009). Indeed, productive efficiency estimated by stochastic frontier analysis is a reliable performance indicator as far as it is accurately estimated. The downside of productive efficiency is that it is sensitive to a number of factors including specifications of the stochastic frontier model as well as the inefficiency effect model, functional form of the frontier model, manipulation of data, procedural issues of estimating inefficiency effect model and so on (see Greene 1990; Ritter and Simar 1997; Bravo-Ureta and Pinheiro 1993; Kalirajan 1991; Kumbhakar et al 1991; Battese and Coelli 1993). Hence, the main challenge relates to having a correct conclusion about the performance of a project.

A good number of corrective means can be adopted towards having reliable estimates when productive efficiency is estimated with stochastic frontier analysis. However, these means do not always give full guarantee for genuine estimates, and this leads us to verify the conclusions drawn on the projects in consideration on the basis of productive efficiency. There are hypotheses tests to select appropriate specifications and functional forms of the stochastic frontier model; however, there are cases where hypotheses tests cannot be applied to select an appropriate specification/procedure for estimating productive efficiency. As for example, the generalised stochastic frontier model can be estimated by a single-stage procedure (see Kumbhakar et al 1991; Battese and Coelli 1993; Wadud and White 2000) or a two-stage procedure (see Kalirajan 1984 and 1985; Kalirajan and Flinn 1983; Pitt and Lee 1981). In fact, there is no hypothesis test to verify which procedure is appropriate; rather there are some arguments against/in favour of each procedure.

On the other hand, the stochastic frontier model can assume at least four distributional specifications, namely, normal-half normal, normal-truncated normal, normal-gamma and normal-exponential; however, the first two distributional specifications are most commonly considered for productive efficiency estimation (see Audibert 1997; Battese and Coelli 1995; Wilson et al 2001; Karagiannis and Sarris 2005; Rahman et al 2012); meaning, the other two are not taken into consideration simply by choice. Similarly, the stochastic frontier model can have a couple of functional forms including Cobb-Douglas, translog and constant elasticity of substitution (CES). But the most commonly used functional forms in the estimation of productive efficiency are Cobb-Douglas and translog. Actually, all the alternative specifications relating to stochastic frontier analysis are not always checked before estimation of productive efficiency. Meanwhile, empirical studies report that estimates of productive efficiency are sensitive to specifications of a stochastic frontier model (see Greene 1990; Ritter and Simar 1997) Considering these realities with the stochastic frontier analysis, it can be contended that there remain some unattended issues which influence the estimates of productive efficiency; hence, it is imperative to employ an alternative/parallel approach to evaluate the same projects in order to verify their evaluation carried out by productive efficiency. A nonparametric approach to productive efficiency can be used as an alternative way of authenticating estimates of productive efficiency with the stochastic frontier analysis; but there are some serious limitations with the nonparametric approach (see Coelli and Battese 1996; Coelli 1995). This study, however, introduces a unique approach to testify evaluation of projects done by the productive efficiency involving stochastic frontier analysis.

ANALYTICAL FRAMEWORK AND METHODOLOGY

The productive efficiency that conforms to the farming practice with the projects is estimated at the first place and then it is authenticated with the alternative approach (hence the yardstick of productivity). Of the three types of productive efficiency, the technical and cost efficiencies are used for project evaluation because of their direct involvement with the performance of production units unlike the allocative efficiency, which actually represents entrepreneurial or managerial performance (Rouf 2016). On the other hand, the two basic types of 'yardstick of productivity' are usually applied to assess the performance of projects. These are 'yield-gap' and 'cost-gap'. Yield-gap is the mathematical difference between yield potential and average farmers' yield (Lobell et al 2009; van Ittesum et al 2013); likewise, cost-gap refers to the mathematical difference between potential cost and average farmers' actual cost. Yardstick of productivity relates to the 'principles of productivity gap' which states that all farms in a production environment cannot exploit the potentials in full for a number of reasons. For example, different types of biophysical factors (e.g., water stress, flooding, fertilizers, water stress, flooding, fertilizers, soil condition etc.) generally affect crop growth in farmers' conditions (Lobell et al 2009). As a result, 'output level per unit of land' or 'cost of production for a given level of output' differs among the farms; meaning, output levels (or costs of production) among the farms would vary leaving a gap between every two farms productive performance. If a farm (say, n-th farm) produces the highest level of output per unit of land (or produces a given amount of output at the minimum cost), the level of output with each of the remaining farm will be less than that of the n-th farm (or costs of production for the same amount of output for each of the remaining farm will be more than the n-th farm). Obviously, level of output (or cost of production) with any farm and the n-th farm maintains a gap, and this is true for any two farms. The existence of these gaps is the main theme of the 'principle of productivity gap'.

Herdt and Mandac (1981) introduced two types of yield-gap in agriculture that are often considered in empirical studies. The first type of yield-gap refers to the difference between the maximum yields at the experimental station and farmers' conditions, while the second type refers to the difference between the maximum possible yield at farmers' conditions and the farmers' actual yield. The first type relates to assessing the impact of agrochemical technologies in different conditions or testing input varieties such as quality of fertilizers, seed types and so on. The second type applies to assessing the comparative performance of different production units under specific conditions. So, the second type of yield-gap is used to authenticate project evaluation performed by technical efficiency. The estimation of potential levels of output requires much effort in measuring yield-gap as per the definition of Herdt and Mandac (1981); however, it can be assessed with less effort involving the estimates of technical efficiency. In fact, technical inefficiency is proportional to the extent of yield-gap theoretically. Again, it (technical inefficiency) can be translated into 'efficiency gap' systematically; this 'efficiency gap' in turn can be converted to 'yield-gap' using standard formulae. By definition, a fully efficient farm produces the maximum possible level of output and its technical efficiency is 'one'. Accordingly, a farm with a technical efficiency of less than one is inefficient. The extent to which the technical efficiency score falls short of one is referred to 'efficiency gap' (Dawson et al., 1991 and Hadley, 2006).

However, the standard formula for calculating the yield-gap, (YLDG), is given by

$$YLDG_i = \left[\left(\frac{YLD_{ai}}{1-TE_{gi}}\right) - YLD_{ai}\right] / FA_i \qquad (1)$$

where, $YLDG_i$ is the yield-gap of the i-th farm; YLD_{ai} is the actual yield of the i-th farm; TE_{gi} indicates the efficiency gap for the i-th farm and FA_i refers to the area of the i-th farm in standard unit (e.g., acre). The expression $(YLD_{ai}/1 - TE_{gi})$ refers to the maximum feasible yield of the i-th farm.

Likewise, the cost-gap for the i-th farm can be assessed drawing on equation (1). If a farm produces a given amount of output with a minimum possible cost, it is called an efficient farm, and if a farm fails to do so, it is called an inefficient farm. A fully efficient farm gets score 'one' while an inefficient farm 'less than one' by definition. The level of inefficiency of a farm is measured by the extent to which cost efficiency score falls short of one, and it is termed as 'efficiency gap' according to (Dawson et al 1991and Hadley 2006). An inefficient farm incurs some extra costs in the production process as compared to the fully efficient farm and 'cost gap' measures the extent to which a farm incurs extra costs. However, the assessment of cost efficiency can be carried out by the following formula

$$CG_{gi} = \left[C_{ai} - \left(1 - CE_{gi}\right)C_{ai}\right] / FA_i \qquad (2)$$

where, CG_{gi} is the extra cost incurred by the i-th farm; C_{ai}, CE_{gi} and FA_i are respectively actual cost, efficiency gap and area of the i-th farm and $(1 - CE_{gi})C_{ai}$ represents the perfectly efficient cost.

Yield-gap calculates the shortfall of output that farms suffer and cost-gap calculates the extra costs that farms incur because of their limitations to exploiting the potentials in full extent. In practice, the mean values of the performance indicators in terms of productive efficiency (e.g., technical efficiency and/or cost efficiency) and yardstick of productivity (e.g., yield-gap and/or cost-gap) are considered primarily to compare the evaluation of the projects. For example, A and B are two projects that are to be evaluated; hence mean productive efficiency score of the farms with project A and B are estimated separately at the first place. Then mean value of yardstick of productivity for the same farms with each of the projects is calculated and thus the performance of the farms/production units is compared. It is expected that outcomes from both of the approaches will come up with identical conclusions. In other words, if conclusions drawn on the basis of outcomes from both of the approaches are incongruent, it would be contended that the productive efficiency has not correctly evaluated the projects.

EMPIRICAL EXAMPLES OF PROJECT EVALUATING

Background of the Projects

Two competing water management projects were implemented in two floodplain areas in the Southwest coastal zone of Bangladesh as safeguards against flooding and waterlogging hazards to protect livelihoods. Since the areas are basically agrarian, the main objectives were to protect agricultural activities particularly, rice and fisheries farming and then to enhance their productivity. It is to be mentioned here that the physical and operational mechanisms of these two water management projects are diametrically different. The first one, the SRM (silt-dredging and regulative-drainage management), is heavily dependent on dredging of silt from the drainage channel and regulation of water flow; importantly, the tides are not allowed to enter the project area; in contrast, the second one, the TRM (Tidal River-basin Management), allows the tides to enter the project area in a planned way in order to exploit the tidal prism. The sediments brought by the tides are deposited on the project area to elevate its ground level; at the same time, sediment-free outgoing tides scour it routes and enhance the capacity of the drainage channels which in turn mitigate flooding and waterlogging problems. The total process is managed conforming to the natural system and without hard engineering structural interventions, whereas the SRM project involves technology-fix hard engineering structures in order to control flooding and waterlogging problems.

However, there was a debate over the appropriateness of these two competing water management projects between the stakeholders and the implementing agency (ADB 1993; SMEC 2002, p. 3; Islam and Kibria 2006, p. 15). The stakeholders were in favour of the TRM project but the implementing agency upheld the SRM project. At one stage, the stakeholders protested against the implementation of the SRM project; eventually, both of projects were implemented. Flood frequency and waterlogging problem under these two projects have been reduced to an acceptable range (ADB 2007) which helps attenuate the debate. But there has been no or little research about these two projects in terms of their contribution to agricultural productivity. It calls for systematic studies about the performance evaluation of the projects to have a wider understanding about them; more specifically, to know which one of the projects is more appropriate for the study area.

Farming Practice and the productive efficiency

Rice and fisheries are the two major agricultural products in the two project areas; however, fisheries production has been taken into consideration for assessing the performance of the two competing water management projects. The reason behind this is that fisheries are the main cash crops that contribute much more to livelihood in the area; again, the practice of fisheries production is on the rise. However, the farming practices and behavioural assumptions relating to fisheries production in the study area do not comply with the Zellner et al., (1966) argument of expected profit maximisation; rather uphold the strategies of cost minimization. So, technical efficiency does not comply with the situation. Besides, output (i.e., fisheries) is not storable for a number of reasons including the farming system of the areas where rice and fisheries are produced in a rotation. These issues lead to the application of cost efficiency for fisheries production. According to Kumbhakar and Lovell (2000, p. 132), ". . . . output is not storable, and so the output maximization objective that underlies the estimation of output-oriented technical efficiency would be inappropriate". However, considering the reality the present study estimates cost efficiency for fisheries production to evaluate the projects and verifies it with cost-gap measures.

Cost Efficiency: Measurement and Related Issues

The typical form of a stochastic cost frontier (SCF) can be expressed as

$$TC_i = g(y_i, c_i; \beta).exp\ (\xi_i + \zeta_i)\,; \qquad i = 1, 2, \ldots., n \qquad (3)$$

where TC_i indicates the actual cost incurred by the i-th production unit (i= 1, 2, 3, ...n)

y_i is a $(1\times \upsilon)$ output vector produced by the i-th farm, i.e., $y_i = (y_{1i}, y_{2i}, \ldots y_{\upsilon i}) \geq 0$;

c_i represents the cost of inputs applied by the i-th production unit, i.e.,

$$c_i \ = \boldsymbol{p}_i \boldsymbol{x}_i = \sum_{i=1}^{n} . \sum_{j=1}^{H} p_{ji} x_{ji}$$

p_i is a $(1\times H)$ vector of input prices against *'H'* number of inputs that apply to i-th farm i.e., $p_i = (p_{1i}, p_{2i}, \ldots p_{Hi}) > 0$; x_i is a $(1\times H)$ vector of units of inputs applied by i-th farm, i.e., $x_i = (x_{1i}, x_{2i}, \ldots x_{Hi}) > 0$; β is a $(H\times 1)$ vector of unknown parameters to be estimated.

The error term, ξ_i represents 'statistical noise' and it can assume either a positive or negative or even a zero value, while ζ_i refers to inefficiency effects and assumes only positive values (Aigner et al 1977). These two error components construct the composed error, ε (i.e., $\varepsilon = \xi_i + \zeta_i$). The inefficiency component ζ_i is assumed to be a function of variables responsible for inefficiency effects as

$$\zeta_i = z_i \delta + \omega_i = \mu_i + \omega_i \tag{4}$$

where, z_i is a $(1\times l)$ vector of farm- and management-specific variables related to cost inefficiency of the i-th farm i.e., $(z_{1i}, z_{2i}, \ldots z_{li}) \geq 0$), and δ is a $(l\times 1)$ vector of unknown coefficients; ω is a random variable assumed to be truncated from a normal distribution, $N \sim (0, \sigma^2_{\omega})$ and the point of truncation is $-z_i\delta$ which maintains $\omega_i \geq -z_i\delta$. In other words, ζ_i is a non-negative truncation of the distribution, $N \sim (-z_i\delta, \sigma_{\zeta}^2)$.

Estimating Cost Efficiency

Estimation of cost efficiency primarily involves probability density functions and joint density functions of the error terms and the composed error term. Then the conditional density of inefficiency term with respect to the composed error is estimated to predict farm specific cost efficiency; it is actually a ratio of the joint density of inefficiency term and composed error to the density of composed error (see Jondrow et al 1982; Kumbhakar and Lovell 2000, p. 82). For equation (3) the conditional density of ζ with respect to ε is given by

$$f(\zeta/\varepsilon) = \frac{f(\zeta, \varepsilon)}{f(\varepsilon)} \tag{5}$$

$$= \frac{1}{\sigma_* \sqrt{2\pi}} . exp\left[-\frac{(\zeta - \mu_*)^2}{2\sigma_*^2}\right] / \left[\left(1 - \Phi(- \frac{\mu_*}{\sigma_*}\right)\right]$$

(6)

where, $\mu_* = (-\sigma^2_\zeta \varepsilon + \mu\sigma^2_\xi)/\sigma^2$, $\sigma^2_* = \sigma^2_\zeta \sigma^2_\xi / \sigma^2$ and φ (.) indicates standard normal density function. Usually, the mean of this conditional distribution $N^+ (\mu_*, \sigma^2_*)$, is used as a point estimator of ζ_i as

$$E(\zeta_i | \varepsilon_i) = \mu_{*i} + \sigma_* \left[\frac{\varphi(-\mu_{*i}/\sigma_*)}{1 - \Phi(-\mu_{*i}/\sigma_*)}\right] \tag{7}$$

where, Φ (.) refers to the standard normal cumulative density function. Parameters μ_* and σ_* are unknown and to be estimated for obtaining the cost efficiency of each farm/production unit. As per the formulation of Battese and Coelli (1988), the cost efficiency of the i-th farm is given by

$$CE_i = E\left\{\exp\left(-\hat{\zeta}_i\right) | \varepsilon_i\right\} \tag{8}$$

$$= \left[\frac{1 - \Phi\left(-\frac{\mu_*}{\sigma_*} + \sigma_*\right)}{1 - \Phi\left(-\frac{\mu_*}{\sigma_*}\right)}\right] . \exp\left(-\mu_{*i} + \frac{\sigma_*^2}{2}\right) \tag{9}$$

The score of cost efficiency CE_i would be less than or equal to 1 (i.e., $CE_i \leq 1$); $CE_i = 1$, only when the inefficiency effect ζ_i is zero, i.e., $TC_i = g(y_i, c_i; \beta) . exp(\xi_i)$; otherwise, $CE_i < 1$.

The mean cost efficiency, $(\widehat{CE})$, of all farms are calculated using the following formula

$$\widehat{CE} = \frac{1}{n} \sum_{i=1}^{n} CE_i \tag{10}$$

Indeed, mean efficiency scores are the most commonly used indicator for project evaluation. The specialised software package FRONTIER 4.1, developed by Coelli (1996), has been used here for the estimation of stochastic cost frontier (SCF) for cost efficiency.

Data collection and the Variables in the SCF

The production environment under the SRM and TRM projects differs and so the varieties of fishery do. The main variety cultivated with the SRM project is freshwater prawn (*Macrobrachium rosenbergii*), and brackish water shrimp (*Penaeus monodon*) is the main variety with the TRM project, although (*Macrobrachium rosenbergii*) variety is often cultivated side by side. The carp variety (locally known as white fish) is most commonly cultivated in each of the projects overlapping with its main variety. However, data on fisheries production were collected in the crop year of 2011/12 adopting multi-stage probability sampling techniques. A total of 357 sample household farms were surveyed; of which 205 household farms belong to the SRM project and the remainder to the TRM project. The survey followed face-to-face interviewing techniques using structured questionnaires.

Farmers in the study area cultivate at least two varieties of fisheries in the same pond over the year, i.e., the production system involves multiple inputs and outputs. Multiple outputs can be converted into a single unit output in a couple of ways (see Sharma and Leung 2000; Iinuma et al 1999; Sharma 1999). However, considering the reality of the area that a part of the output is consumed by the producers the following formula is adopted

$$W_{ji} = \sum_{j=1}^{\nu-1} \left(\frac{P_{ji}}{P_{\nu i}}\right). Q_{ji} \; + \; Q_{\nu i} \qquad (11)$$

where, W_{ji} indicates the weighted average of the multiple outputs of the i-th farm $(i = 1, 2, 3, \ldots N)$ and P_{ji} is the price of j-th output of $(j = 1, 2, 3, \ldots \upsilon)$ offered to the i-th farm. In order to convert other outputs into a single unit, υ-th output has been used as the reference. Price offered to the υ-th output of the i-th farm is $P_{\upsilon i}$; quantity of the reference output produced by the i-th farm is $Q_{\upsilon i}$ and the quantity of the j-th output produced by the i-th farm is Q_{ji}. Drawing on Iinuma et al (1999), the standardized weighted average of output quantities is given by

$$y_i = W_{ji}/A_i \qquad (12)$$

where, the standardized output of i-th farm is y_i, and A_i is the size of the i-th farm in acres.

Likewise, multiple inputs of the same variety are converted to a single unit to gain some advantages in estimation process including avoidance of too many parameters (see Caves et al 1980 and 1982; Kumbhakar 1991). The following formula is used for converting multiple inputs of fish seeds

$$X_i^{\bar{G}} = \left[\prod_{k=1}^{\theta} \frac{C_{ki}}{M_{ki}}.1000\right]^{1/\theta} \qquad (13)$$

where $X^{\bar{G}}_i$ refers to the geometric mean of the prices of different species of fish seeds; M_{ki} and C_{ki} are respectively the number of seed of the k-th species released into the fish pond and its cost incurred by the i-th farm $(k = 1, 2, 3, \ldots \theta)$. It is to be mentioned here that generally fingerling price is calculated per thousand counts.

Table1

Descriptive statistics of the variables in the SCF model
(Values are against per acre of farm)

Variables	Project	Mean	Std. Dev	Max	Min	t-ratio
Fingerling price (tk)	SRM	2935.69	727.90	6928.20	1400.00	23.32***
	TRM	1454.79	469.12	3949.68	681.70	(0.00)
Pond preparation cost (tk)	SRM	8126.27	5437.35	28947.37	373.98	8.53***
	TRM	4413.52	2626.77	11250.00	526.32	(0.000)
Feed price (tk)	SRM	25.83	6.73	78.62	14.29	-2.36**
	TRM	27.49	6.38	45.00	11.71	(0.019)
Medicine cost (tk)	SRM	993.12	1096.94	7733.33	0.00	6.36***
	TRM	455.57	439.86	2155.17	0.00	(0.000)
Medicine Dummy	SRM	0.93	--	1.00	0.00	--
	TRM	0.82	--	1.00	0.00	--
Total output (kg)	SRM	166.65	108.85	602.18	14.89	-1.18
	TRM	178.22	75.69	403.51	19.82	(0.237)
Farm-specific variables						
Age	SRM	39.83	11.03	70.00	18.00	1.64
	TRM	37.91	10.82	70.00	19.00	(-0.102)
Education	SRM	8.25	3.65	17.00	0.00	-1.101
	TRM	8.65	2.97	15.00	0.00	(0.272)
Ownership Dummy	SRM	0.64	--	1.00	0.00	--
	TRM	0.32	--	1.00	0.00	--
Extension Dummy	SRM	0.20	--	1.00	0.00	--
	TRM	0.53	--	1.00	0.00	--
Total Cost (tk)	SRM	59373.34	36397.24	215333.33	3557.10	2.58**
	TRM	51388.60	21662.55	135789.47	9808.50	(0.010)

Note: *** significant at 1% level ($p<.01$)
** significant at 5% level ($p<.05$)
* significant at 10% level ($p<.10$)

(Figures in the parentheses indicate p-values)
Source: Field survey

Table 1 reports important statistics of the variables relating to the stochastic cost frontier models for fisheries production with the SRM and TRM projects. Independent sample t-test and F-test (Levenes' test of equal variance) reveal that means and standard deviations of the variables are different; on the other hand, bivariate correlation coefficients provide no sign of collinearity problem among the variables (see Appendix tables A1 and A2).

HYPOTHESES TESTS

The precondition for estimation of a stochastic cost frontier (SCF) model is that inefficiency effects, ζ_i, are stochastic and have particular distributional properties (Coelli and Battese 1996; Coelli 1995). Besides, there are some other specifications relating to the SCF model to be known ahead of estimation and hence different types of hypothesis tests are executed. However, the following hypotheses tests are carried out using the generalized likelihood-ratio statistic, λ, given that $\lambda = -2\,[\ln\{L(H_0)\} - \ln\{L(H_1)\}]$, where $L(H_0)$ and $L(H_1)$ respectively refer to the values of the likelihood function with the null (H_0) and alternative (H_1) hypotheses. Table 2 presents the outcomes of these hypotheses tests.

The first hypothesis test confirms the presence of inefficiency effects in the SCF model, which implies that the traditional average response model (OLS) is inadequate for the SCF model of fisheries production, i.e., the SCF model is justified here. The second hypothesis test reveals that the variances of the inefficiency effects are not zero, i.e., the inefficiency effects are stochastic. The third and the forth hypotheses tests relate to the distributional specification of the inefficiency model; the third test rejects the null hypothesis that the intercept and all the coefficients of the farm related variables are zero, i.e., the traditional half-normal distribution as originally proposed by Aigner et al (1977) is not appropriate for the inefficiency model, while the fourth hypothesis test fails to prove that coefficients of all the explanatory variables in the inefficiency effect model are zero, meaning the cost inefficiency model follows truncated normal distribution.

Table 2
Test of hypotheses

Null hypothesis	Log-likelihood value	Test statistic (λ)	Critical value ($\chi^2_{0.95}$))	Decision
SRM project				
(1a) H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$	69.37	17.57	11.91	Rejected
(2a) H_0: $\gamma = 0$	65.77	10.38	5.14	Rejected
(3a) H_0: $\delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$	67.41	13.65	9.49	Rejected
(4a) H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$	66.24	11.32	7.82	Rejected
TRM project				
(1b) H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$	18.71	28.44	11.91	Rejected
(2b) H_0: $\gamma = 0$	7.57	6.16	5.14	Rejected
(3b) H_0: $\delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$	15.73	22.50	9.49	Rejected
(4b) H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$	15.62	22.27	7.82	Rejected

Note: *Mixed* $\chi^2_{v,\,0.95}$ *values are taken from Table 1 of Kodde and Palm (1986).*

Empirical SCF Model

The crucial role of cost efficiency is widely recognised by researchers (see Bhattacharyya and Kumbhakar 1995; Hesmati and Kumbkakar 1997; Hiebert 2002; Rahman 2002) as well as policy makers. Meanwhile, Cobb-Douglas and translog are the two dominant functional forms in stochastic frontier analysis (Battese 1992; Bravo-Ureta and Pinheiro 1993; Darku et al 2013). When data contains a considerable number of zero observations it is recommended to use a Cobb-Douglas model instead of a translog model to avoid too many zeros in the data set which lead to biased estimates. According to Bravo-Ureta and Pinheiro (1993), the impact of the functional form on key results of the study should be taken into consideration. However, the cost frontier of the present analysis fits the Cobb-Douglas model primarily because of zero observations in data[1].

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[1] Some farmers in the study area skip application of medicine in the fisheries production; so there are zero observations in the data set.

The Cobb-Douglas functional form of the stochastic cost frontier model is expressed as

$$ln\, TC_i = \beta_0 + \sum_{j=1}^{5} \beta_j \, ln\, p_{ji} + \beta_v \ln y_{\upsilon i} + \xi_i + \zeta_i \qquad (14)$$

after normalization it takes

$$\ln\left(\frac{TC_i}{p_{(5th)i}}\right) = \beta_0 + \sum_{j=1}^{4} \beta_j \, ln\left(\frac{p_{ji}}{p_{(5th)i}}\right) + \beta_\upsilon \ln y_{\upsilon i} + \xi_i + \zeta_i \qquad (15)$$

The price of the 5-th input has been used for normalization, so the effective number of inputs in the model is 4; meaning (5×1) vector of unknown parameters reduces to (4×1) vector of parameters. Turning to addressing the zero observation in the Cobb-Douglas model

Unless treated in a proper way, zero observations in a Cobb-Douglas functional form may reduce the likelihood of obtaining unbiased estimates. This problem is addressed following the Battese (1997) procedure where zero observations are adjusted with dummy variables. This is a statistically sound procedure had been used in a good number of empirical studies (e.g., Battese et al 1993 and Coelli 1995). However, the following are the adjusted empirical models for estimating cost efficiency of the projects.

The Main Model

$$ln\, TC_i = \beta_0 + \sum_{j=1}^{3} \beta_j \, ln\, p_{ji} + \beta_4 \, ln\, [\max\,(p_{4i}, 1 - D_{1i})] + \beta_5 D_{1i} + \beta_6 \ln y_{\upsilon i} + \xi_i + \zeta_i \qquad (16)$$

and the subsumed inefficiency effect model

$$\xi_i = \eta_0 + + \sum_{l=1}^{4} \eta_l \, ln\, z_{li} + + \omega_i$$

where, the subscript i $(i = 1, 2, 3, \ldots n)$ refers to the i-th farm and the subscript $l (l = 1, 2, 3, 4)$ indicates inefficiency variable. *In* TC_i is the natural log of total cost (tk) for the i-th farm; p_1, p_2, p_3 and p_4 indicate respectively the cost/price of farm preparation, feed, fuel, and medicine against per unit of land; y refers to yield per acre of land and D_1 denotes the dummy for medicine. Age and education of the farm operator are indicated respectively by z_1 and z_2 , while z_3 and z_4 are the dummies for ownership of the farm and extension service respectively; if the farm operator himself is the owner of the farm, z_3 takes 'one and zero otherwise; if extension service is present, z_4 takes 'one' and 'zero' otherwise.

Table 3
Estimates of the stochastic cost frontier and inefficiency models with project SRM

Variables	Parameters	Coefficient (Std. error)	t-ratio
Constant	α_0	1.00 (0.46)	2.18***
ln p_1 (Fingerling price)	α_1	0.44 (0.10)	4.33***
ln p_2 (Farm preparation cost)	α_2	0.19 (0.03)	5.54***
ln p_3 (Feed price)	α_3	0.49 (0.09)	5.45***
ln p_4 (Medicine)	α_4	0.06 (0.03)	2.15**
D_1 (*Medicine Dummy)*	α_5	0.35 (0.11)	3.06***
ln y_1 (Total yield)	α_6	0.59 (0.04)	15.50***
Inefficiency model			
Constant	η_0	-2.58 (1.28)	-2.02**
h_1 (Age of the farm operator)	η_1	0.02 (0.01)	1.93*
h_2 (Education of the farm operator)	η_2	0.08 (0.03)	2.18**
h_3 (Ownership Dummy)	η_3	0.15 (0.19)	0.79
h_4 (Extension service Dummy)	η_4	-3.60 (1.85)	-1.95*
Diagnosis statistics			
Sigma-squared	σ^2	0.45 0.13	3.46***
Gamma	γ	0.85 0.04	19.46***
Log-Likelihood		-60.58	

Note: *** significant at 1% level ($p<.01$)
**significant at 5% level ($p<.05$)
* significant at 10% level ($p<.10$)

(Figures in parentheses are OLS estimates)
Source: Own estimation

Table 4

Estimates of the stochastic cost frontier and inefficiency models with project TRM

Variables	Parameters	Coefficient (Std. error)	t-ratio
Constant	α_0	2.79 (0.34)	8.16***
$\ln p_1$ *(Fingerling price)*	α_1	0.38 (0.08)	4.98***
$\ln p_2$ *(Farm preparation cost)*	α_2	0.08 (0.03)	2.43**
$\ln p_3$ *(Feed price)*	α_3	0.06 (0.10)	0.62
$\ln p_4$ *(Medicine)*	α_4	0.10 (0.03)	3.35***
D_1 *(Medicine Dummy)*	α_5	-0.23 (0.08)	-2.89***
$\ln y_1$ *(Total output)*	α_6	0.42 (0.05)	8.10***
Inefficiency model			
Constant	η_0	0.50 (0.29)	1.72*
h_1 *(Age of the farm operator)*	η_1	-0.02 (0.01)	-0.36
h_2 *(Education of the farm operator)*	η_2	-0.01 (0.02)	-0.37
h_3 *(Ownership Dummy)*	η_3	0.13 (0.11)	-1.17
h_4 *(Extension service Dummy)*	η_4	-0.47 (0.21)	-2.18**
Diagnosis statistics			
Sigma-squared	σ^2	0.10 (0.04)	2.90***
Gamma	γ	0.72 (0.14)	5.33***
Log-Likelihood		-4.49	

Note: *** significant at 1% level (p<.01)
**significant at 5% level (p<.05)
* significant at 10% level (p<.10)

(Figures in parentheses are OLS estimates)
Source: Own estimation

Findings from SCF Model

All the variables in the stochastic model for both of the projects are significant except one variable with the TRM project; again, the level of significance for most of the significant variables is very high (i.e., $p<0.01$); more importantly, the signs of the coefficient are as expected. These indicate that the models truly represent the production regimes with both of the water management projects. The mean cost efficiency score of the farms with TRM and SRM projects are respectively 0.7622 and 0.8068; meaning cost of production per unit could be reduced by approximately 24% and 20% keeping output level unaffected with the TRM and SRM projects in order. So, the SRM project performs better than the TRM project as far as fisheries production is concerned. The cost efficiency scores of the farms with TRM project vary from 0.4260 to 0.9504, having a standard deviation of 0.1281, while the range of these scores with SRM project is 0.2634 to 0.9533, with a standard deviation of 0.2753. In order to obtain further information about the projects, skewness and kurtosis of the cost efficiency scores are calculated (table 5). It is found that coefficient of skewness of the cost efficiency scores with SRM is relatively more left-skewed, i.e., proportionately a higher number of farms belonging to SRM is placed on the right of the mean efficiency. Meaning, farms with SRM are better performed compared to TRM. Meanwhile, the coefficient of kurtosis reveal that efficiency score with SRM and TRM are respectively leptokurtic and platykurtic, and these patterns also in line with the previous results. These findings establish that the SRM surpasses the TRM but by a small margin.

Table 5

Coefficients of skewness and kurtosis for efficiency scores by project

Project	Coefficient of Skewness	Std. error	Z-value	Coefficient of Kurtosis	Std. error	Z-value
SRM	-1.73	0.17	-10.17**	4.15	0.34	12.23**
TRM	-0.75	0.2	-3.82**	-0.41	0.39	1.06

** Significant at 5% level
Source: Own calculation

Statistical Tests for More Precise Judgement

In order to check if the mean scores are statistically different from each other, independent sample t-test is carried out and Levene's test is for equality of variance (table 6). These tests reveal that mean cost efficiency for the farms with SRM and TRM are statistically different (t=3.383 with 355 degrees of freedom) and equal variances for the cost efficiency scores with the projects (F = 5.901 with 355 degrees of freedom) does not hold true.

Table 6

F-test and independent sample t-test for cost efficiency

Projects	Mean score	Std. dev	Max	Min	F-test	t-test
SRM	0.81	0.28	0.95	0.26	5.90**	3.35***
TRM	0.76	0.13	0.95	0.43	-0.02	0.00

**Significant at 5% level, ***Significant at 1% level Source: Own calculation

If the difference between the mean values is small and it is statistically significant while the sample size is large, it is recommended to check the result again to know whether it is acceptable or not (Pallant 2011, p. 210). A measure of 'effect size' (or 'strength of association') can provide the level of acceptance of the result (Tabachnick and Fidell 2007, cited in Pallant 2011, p. 210). The most commonly used effect size statistics are 'partial eta-squared' and 'Cohen's d'; however, this study adopts 'partial eta-squared' because of its popularity in social sciences.

Eta-Squared, τ^2, is measured by

$$\tau^2 = t^2 / (t^2 + s_1 + s_2 - 2) \quad (17)$$

where, t refers to the 't-ratio' that appear in the independent sample t-test, and s_1 and s_2 are the sample sizes.

$$\text{Therefore, } \tau^2 = (3.347)^2 / (3.347^2 + 152 + 205 - 2) \quad (18)$$

$$= 0.03 \text{ or } 3\%$$

The value of eta-squared falls between the small and the medium range; that means, the management projects explain only 3% of the variance in the efficiency ratings of fisheries production (see Appendix B). In other words, the scores are not significantly different from one another.

The stochastic frontier analysis has evaluated the two projects with cost efficiency and concluded that the SRM marginally outperforms the TRM as far as fisheries production is concerned. Now, these two projects to be evaluated by the yardstick of productivity approach using cost-gap and it's variant in order to check if the earlier evaluation is not different from the present one.

COST-GAP AND REEVALUATION OF THE PROJECTS

Measuring Cost-gap

The SRM and TRM projects have been re-evaluated primarily by a powerful yardstick of productivity, cost-gap measure. In addition, potential cost saving (PCS), a variant of cost-gap, is also used for this purpose. 'Cost-gap' refers to the performance of a farm/production unit in terms of excess cost that it incurs in the production process. The formula given in equation (2) has been use to calculate the cost-gaps and mean cost-gaps for the farms with each of the projects and presented in the table 8.

The cost-gap ratio: Towards more Precise Assessment

Absolute differences between (average) cost-gaps with different projects are taken into consideration for comparing them in terms of productive performance. The limitations here is that absolute differences do not reveal the relative sizes of the cost-gaps, so this measure lacks some information about the performance of the projects. 'Cost-gap ratio' is such a supplementary measure that can overcome the limitations by providing relative sizes of the cost-gaps involved. In calculating a 'cost-gap ratio', the highest one of the cost-gaps is used as the numerator; so, the ratio can take a value between unity and infinity. Considering the expected sizes of the cost-gaps, the range of values of the ratio is set up. In order to make the comparison with ease, it is better to keep the range as minimum as possible. However, the range of values of the ratios lies between 1 and 2 for the present study. Based on this range, the ratios are classified into five categories (table 7) to have a quick overview of the relative sizes of the cost-gaps in consideration.

Table 7

Classification of cost-gap ratios based on relative sizes of cost-gaps

Types of cost-gap *(by name)*	Range of ratios *($1 \leq$ ratios $\leq \infty$)*	Comment *(on cost-gaps)*
1. ND (No difference)	1	exactly the same
2. LD (Little difference)	1< ratio <1.25	very close to each other
3. MD (Medium difference)	1.25< ratio <1.50	not very close to each other
4. HD (High difference)	1.50 < ratio <1.75	Large gap
5. VHD (Very high difference)	1.75 < ratio	Very large gap

Source: Own calculation

When the ratio is one, both of the cost-gaps are the same and this category is termed as No Difference (ND) (between the cost-gaps); if the ratio falls between 1 and 1.25, the category is termed as Little Difference (LD), here the cost-gaps are very close to each other.

Likewise, for every addition to the previous range by 0.25 point sets the next higher category and it ends at 2 or more. The third and the fourth categories are respectively identified as Medium Difference (MD) and High Difference (HD) respectively. The range of the fifth category starts with 1.75 and it refers to a large gap between the cost-gaps. This is the last category and it is termed as Very High Difference (VHD). However, the ratio of cost-gap between the two projects is only 1.15 which indicates that there is a 'little difference' between the projects.

Potential Cost Saving: A Variant of Cost-gap

'Potential cost saving' (PCS) is often used along with ‘cost-gap’ for a thorough understanding of the relative performance of production units. PCS refers to an amount of cost that could have been saved if the farm were cost efficient, and it is calculated against hundredweight. Measures of PCS can be shown against different logical groups/segments of the farms which provide a comparative performance of the project in detail.

The following formula provides the measure of potential cost saving (PCS).

$$PCS_i = \frac{\{(1 - CE_{gi})C_{ai}\} - C_{ai}}{C_{ai}} \times 100 \qquad (19)$$

(Notations bear the same meanings as before)

However, if the average PCS for the farms with project A is smaller than that with project B, project A is said to have performed better than B.

However, the cost-gaps per acre of land with SRM and TRM projects are respectively tk. 12542.71 and tk. 14440.39 for fisheries production, i.e., on average the gap is higher with the TRM project than that with the SRM by a margin of tk. 1897.673 per acre (table 8). Meanwhile, the ratio between the cost-gaps for TRM and SRM is only 1.15 (table 8). The cost-gap ratio falls into the lower range of the classification and it suggests that there is little difference between the cost-gaps with the projects.

Table 8
Cost-gaps and cost-gap ratios by project

Projects	Average amount of gap	Std. dev	Max	Min	Difference between gaps	Ratio between gaps
SRM	12542.71	13031.88	92516.8	257.28	1897.67	1.15
TRM	14440.39	13587.99	74256.36	600.15		

*Figures in the parentheses indicate the p-values
Source: Own calculation

Measuring Potential Cost Saving

The concept of ‘cost-gap’ provides a gross measure of the relative performance of production units, while ‘potential cost saving’ (PCS) provide a more specific measure in this regard. In addition to an overall measurement (i.e., considering all the farms together), PCS can also be measured against different logical groups/segments. The latter approach of measuring PCS actually provides a thorough understanding of the comparative performance of the projects. The present study, however, measures PCS against top 20%, middle 20% and bottom 20% farm groups in addition to an overall PCS using the formula given in equation (19).

Table 9 shows that the potential cost saving (PCS) and relevant statistics. It is seen that the gap between observed cost and economically efficient cost becomes narrower with the increase of efficiency level. In other words, PCS declines as the level of efficiency rating increases. However, PCS with the TRM is higher than that with SRM for the all-farms group as well as for the 20% groups. These findings re-establish that SRM project performs better than TRM as far as fisheries production in concerned. Further, the difference between potential cost savings against each of the corresponding farm group with SRM and TRM is very small. These findings show that the two the projects are very close to each other in terms of potential cost saving.

Table 9
Potential cost saving by farm group

Project	Farm group	Actual cost (average)	Efficient cost (average)	Potential cost saving (%)	Std. dev	t-test
SRM	Bottom 20% farms	70569.74	43675.93	37.93	12.08	-3.19^{***} (0.00)
TRM		80793.30	44083.55	44.80	5.68	
SRM	Middle 20% farms	57293.92	47583.45	17.08	1.32	-7.44^{***} (0.00)
TRM		48288.50	38315.99	20.46	2.22	
SRM	Top 20% farms	43776.59	40616.36	7.20	1.39	-5.65^{***} (0.00)
TRM		30975.13	27931.76	9.59	1.99	
SRM	All-Farms	59373.34	47914.29	19.33	11.94	-3.38^{***} (0.00)
TRM		51388.60	39158.11	23.78	12.81	

Note: *** Significant at 1% level
** Significant at 5% level
(Figures in the parentheses indicate the p-values)
Source: Own calculation

CONCLUSION

Project evaluation in agriculture by a parametric approach involving productive efficiency calls for authentication because of the fact that productive efficiency is sensitive to a good number of factors including specifications of stochastic frontier analysis. This study authenticates evaluation of two competing agricultural projects, the SRM and the TRM, by employing a novel approach, the yardstick of productivity. The parametric approach engaged estimates of 'cost efficiency' to evaluate the projects while the yardstick of productivity approach exploited the measure of 'cost-gap' to verify this evaluation. However, findings from both of the approaches end up to a consistent conclusion that the SRM project surpasses the TRM project as far as fisheries production is concerned.

Further, precise differential measurements relating to both of the estimates, e.g., cost efficiency and cost-gap are employed for verification of the evaluation. The measure of 'effect size' is computed for cost efficiency scores while 'cost-gap ratio' and 'potential cost-saving' are calculated for cost-gap measures. The value of 'eta-squared' falls between the small and the medium range which implies that the mean cost efficiency scores with the projects are not significantly different. Meanwhile, the cost-gap ratio between the two projects is only 1.15 which indicates that there is a 'little difference' between them. The difference between corresponding 'potential costs saving' against each of the farm groups with the projects is exiguous. These results clearly show that the estimates of cost efficiency and the measures of cost-gap come up with identical conclusions that the SRM project outperforms the TRM project by a small margin. The above findings suggest that evaluation of the two projects by the estimates of cost efficiency is genuine and uphold the real situation.

The measure of 'effect size' was conducted employing 'partial eta-squared' based on the cost efficiency scores while cost-gap ratio and potential cost-saving (PCS) are calculated relating to cost-gaps. The value of eta-squared falls between the small and the medium range; that means, the mean cost efficiency scores are not significantly different from one another. Meanwhile, the cost-gap ratio between the two projects, SRM and TRM, is only 1.15 which indicates that there is a 'little difference' between them. The difference between corresponding potential costs saving against each of the farm group is exiguous. These results clearly show that the estimates of cost efficiency and the measures of cost-gap come up with identical conclusions that the SRM project outperforms the TRM project by a small margin. The above findings suggest that evaluation of the two projects by the estimates of cost efficiency is genuine and uphold the real situation.

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Appendix A

Bivariate correlation coefficients between the variables in the Stochastic Cost Frontier (SCF)

Table A1

Pearson Correlation (rank zero) for the variables in the SCF with SRM project

Variables	Fingerling price	Farm prep cost	Feed price	Medicine	Yield	Total cost
Fingerling price	1					
Farm prep cost	0.03	1.00				
Feed price	-0.03	0.04	1.00			
Medicine	0.13	0.36**	0.10	1.00		
Yield	0.09	0.41**	0.01	0.43**	1.00	
Total cost	0.21**	0.53**	0.13	0.57**	0.79**	1.00

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table A2
Pearson Correlation for the variables in the SCF with TRM project

Variables	Fingerling price	Farm prep cost	Feed price	Medicine	Yield	Total cost
Fingerling price	1.00					
Farm prep cost	0.10	1.00				
Feed price	.241**	-0.12	1.00			
Medicine	0.03	0.02	0.03	1.00		
Yield	0.14	.28**	0.14	0.15	1.00	
Total cost	.326**	.307**	.208*	.179*	.625**	1.00

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Appendix B

According to the guidelines proposed by Cohen (1988, p. 22 cited in Pallant, 2011, p.210), the strength of the size effects for eta-squared and Cohen's d are classified as

Effect Sizes	Eta-squared (τ^2)	Cohen's d
Small	0.01 or 1 percent	0.2
Medium	0.06 or 6 percent	0.5
Large	0.138 or 14 percent	0.8

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