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# TECHNICAL EFFICIENCY OF THE HATCHERY OPERATORS IN FISH SEED PRODUCTION FARMS IN TWO SELECTED AREAS OF BANGLADESH

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## ABSTRACT

This study is concerned with the estimation of technical efficiency of the hatchery operators producing fish seeds. Using 50 samples comprising 25 each from Jessore and Mymensingh districts, the study has used the Frontier 4.1 package to estimate the technical efficiency of the hatchery operators. A Cobb-Douglas production function with six quantitative variables namely, water area, human labour, feed, fertilizer, number of brood fish and proportion of hormone dose given to female brood and a regional dummy for the stochastic frontier and a linear technical inefficiency function with 4 variables: education, experience, number of training received and salary of the operators were jointly estimated. Several hypotheses tests were performed using Log-Likelihood Ratio Test. Some policy suggestions were also provided. The mean technical efficiency of the hatchery operators was 61 percent. Technical efficiencies were not found to be skewed towards higher or lower scores, rather concentrated on the $20^{th}$, $30^{th}$, $80^{th}$ , and $90^{th}$ percentiles. Hypothesis of no existence of inefficiency effect was rejected establishing that significant inefficiency exists. More than one-third of the seed production potential remains unutilized. Utilizing the unexploited production potential of the fish seed producers rather than establishing new farms and hatcheries appears to be the pertinent policy. Training of the farm/hatchery operators can help achieve the unexploited potential.

## I. INTRODUCTION

Fish catches and productions are not keeping pace with its growing demand. Over the last decade, annual per capita fish consumption has declined from 12 kg to 7 kg in Bangladesh. In other words, there *is* a great shortage of fish production in this country and this situation is gradually aggravating day-by-day due to rapid growth of population. This situation requires the improvement of natural fish habitats and new ways of increasing fish production appropriate to the community and the environment. Increased aquaculture production can help to meet the increased domestic demand for fish and also to meet protein availability. But the availability of better quality of fish seed is essential to the establishment of aquaculture industry. To meet the increasing demand or quality fish seed in private sector, Department of Fisheries (DOF) has strengthened the existing public sector fisheries centers and encouraged the establishment of private sector fish hatcheries. The shortage of fish seeds/fingerlings is one of the biggest problems in this country for which fish production is not increasing as rapidly as it is expected. For this purpose the DOF undertook establishment of 110 Fish Seed Multiplication Farms (FSMFs) covering almost all the districts of Bangladesh.

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Likewise, around 779 private hatcheries have currently been established in different areas of the country which are also producing fish seed.

Without getting high yielding species and quality fish seeds in time, fish culture in inland water bodies cannot be ensured and fish production will continue to suffer. The supply of fish seed does not depend only on the collection of spawn from the hatcheries and the natural sources, but it also depends on the survivability of spawn during the process of rearing the same as fingerlings in the nursery ponds. Now-a-days, it appears that fish seed production technology has been transferred to the private enterprises. With the increasing demand for quality fish seed for aquaculture practices, the participation of private sector in this business becomes substantial.

For production of fish spawn/seed, healthy brood and its management is very essential. In Bangladesh, with the expansion of hatcheries, availability of big sized and healthy brood fish are increasingly becoming a problem as open water fisheries deplete. There is, thus, a tendency to use small and unhealthy brood as well as their undesirable crossing. This has resulted in the increased supply of spawn, which after rearing in nursery ponds, enter into the stream of fry-fingerling supply. Since the parent fish are either immatured or are undesirably crossbred, the spawn and subsequently fry-fingerling are of poor quality. The poor quality is interpreted in terms of high mortality, low growth, disease susceptibility and so on which, adversely affects the table sized fish production of the country. Technical inefficiency of the concerned operators in the production of seed poses another problem. Thus mere increase in the number of FSMFs hatcheries and hatching facilities may not assure increased supply of quality fish seed, the operators must be able to explore the fullest production potential.

Investigations on fish culture have been done by various researchers (Islam et al. 1997; Dey,2000; Sharma and Leung, 1998, 1999, 2000a, 2000b; Arjuman Ara, 2001; Rashid and Chen, 2002; Khan, 2003). Of these investigations carp polyculture received priorities as this is the most widely practiced fish culture technologies in Bangladesh. A good number of socioeconomic investigations have also been made on fish culture technologies (Islam and Dewan 1987, 1888; Miah, 2000; Malek, 1997; Khan, 1996; Rahman, 1995), study relating to technical efficiency of the fish farmers in general and fish hatcheries in particular in Bangladesh received less attention from the researchers. This study aims at investigating into the aspects of technical efficiency of the hatchery operators of the FSMFs so that level of inefficiency, if any, exists can be identified along with its implications in the fish seed as well as table fish production in the country. No technical efficiency study on hatchery for the production of spawn has been made. Thus this study is expected to provide meaningful insights into the level of technical efficiency of the hatchery operators along with factors affecting inefficiency.

This study is organized into five sections. Following introduction, the second section highlights chronological development of FSMFs and fish seed production. Section three addresses the methods comprising data, and analytical techniques and construction of empirical model including brief conceptual issues on technical efficiency. Results and discussion of the study are then presented in section four. Finally, concluding comments and policy implication of the study have been presented in section five.

## II. DEVELOPMENT OF FISH SEED MULTIPLICATION FARMS AND SEED PRODUCTION

Fish hatchery is mainly a facility for hatching fish seeds. It constitutes an important component of a fish farm. A fish farm may comprise a nursery and/or rearing and /or stock ponds. A few years ago rivers were the main sources of carp seed. In recent times, however, consequent to the development of the technique of induced breeding of carps, the connotation of a hatchery has been enlarged to include facilities for producing spawn, fingerlings suitable for stocking and growing in ponds. A complete fish farm producing table-sized fish comprises a hatchery to produce hatchlings, nurseries to produce fry, rearing ponds to produce spawn, fingerlings and stock ponds to grow fingerlings to table-size fish. A fishery establishment may have only a hatchery or only nursery or rearing or stocking ponds or both hatchery and stocking ponds. The magnitude of operation of each type is highly variable, ranging from just a few spawning to large scale commercial operations in both the section of fish farm.

The major input in culture fishery is the quality fish seed. The expansion and development of aquaculture production depend mainly on the availability of seed. The source of fish seed in Bangladesh is spawn collected from rivers and those produced in government and private hatcheries. But natural breeding grounds are beset with many problems: (i) undesirable predator fish seed may come along with expected fish seed; (ii) infected and bad quality seed may come which may seriously affect the scientific fish culture. Moreover, wild seed is collected and handled in a crude and unscientific method, which leads to a large-scale mortality during transportation from collection centers to nursery ponds and also in the nursery ponds after release. Thus, though large quantities of fish seed are collected from rivers, affecting natural recruitment to riverine fisheries and riverine fish production, its contribution to aquaculture is not commensurate with the efforts.

In order to get rid of the problems, hatching facilities should be enlarged to supply sufficient quality fish seed needed for fresh water and brackish water aquaculture development. In view of this, Government of Bangladesh has given great emphasis on large scale hatchling production, nursery and rearing of selected fast growing aquatic carp fingerlings. Besides carps, seed production of *Magur, Koi, Puti* etc, has also been encouraged (Planning Commission, 1991).

During the 1970s the public sector of the country began producing quality fish seed through artificial breeding techniques for government fish farms by establishing a number of fish hatcheries. During the middle 1980s basic training in fish breeding and hatchery operation and management was undertaken, initially by the Department of Fisheries (DoF), and later by the Bangladesh Fisheries Research Institute (BFRI). The private sector was instrument in building a good number of hatcheries. During 1988 the public and private sectors established 77 and 162 hatcheries, respectively. The number rapidly increased during the last ten years to 779 with the private sector predominating in the development of fish hatcheries in the country.

With the success in production of fish seed through induced breeding and the increasing demand for quality fish seed for aquaculture practices, the Government of Bangladesh established a number of hatcheries in public sector in different parts of the country. Presently, fish seed is collected from rivers and also produced in the private and public hatcheries. The species mainly cultured in fresh water and the seeds of which are produced are: Rui, Catla, Mrigal, Silver Carp, Grass Carp, Mirror Carp, Thai Puti, Carpio, Kalibous, Bighead carp Magur and Koi. Spawn is collected during the monsoon season from the rivers: the Halda, the Jamuna, the Padma, the Brahmputra and their tributaries.

**Table 1. Spawn/Hatchling and fry production of carp**

| Year | Spawn Hatchling (kg) | | | | Fry from public source (in million Nos.) |
|---|---|---|---|---|---|
| | Natural source (1) | Public source (2) | Private source (3) | Total (1+2+3) | |
| 1993 | 5069 | 3263 | 45701 | 54033 | 21.707 |
| 1994 | 5872 | 3180 | 69356 | 78408 | 17.479 |
| 1995 | 9144 | 3272 | 97205 | 109621 | 22.575 |
| 1996 | 2399 | 3615 | 112595 | 118609 | 2.9085 |
| 1997 | 2824 | 3888 | 137042 | 143754 | 35.055 |
| 1998 | 2885 | 3700 | 114400 | 120985 | 36.900 |

*Source: Adopted, from DOF (1999).*

Around 8.8 billion seeds are collected annually from these rivers. Collection of seed from natural waters has currently been declining in the country. As against an estimated collection of 24 billion seed during 1983, the seed collected during 1987 was only one third of 1983 collection (Islam, 1989).While natural seed collection has been declining, private sector fish seed production is increasing day by day (Table 1). Now-a-days more than 90 percent spawn requirement are met from induced breeding (DOF, 1999).

In recent years, there has been a phenomenal growth in the number of hatcheries, especially in the private sector. In 1982, there were only 3 private hatcheries in Bangladesh. The number has increased to 40 by 1985 and to 214 by 1987, producing 2.75 billion spawn annually, the rate of annual increment being 170 percent. The size and production capacity of these private hatcheries vary, ranging from 8 to 160 million spawn annually.

In addition to 214 hatcheries in private sector, there are 110 hatcheries in the public sector. The annual production of spawn from the public sector hatcheries is around 584 million. At present, as many as 779 private hatcheries have been developed. The annual production of spawn from this sector is around 2,20,217 kg in 2000-2001. It can also be noted here that the number of shrimp hatchery is 43 in Bangladesh (DoF, 2002).

There is no actual figure as to what amount of fish seed is needed annually for culturing in stocking ponds and other waterbodies in this country. But it has been observed that the demand for fish seed is very high during stocking period year to year, but the real fact is that both demand and price of fish seed have gradually been increasing for the last couple of years (Islam and Dewan, 1987, 1988).

## III. DATA, ANALYTICAL TECHNIQUE AND EMPIRICAL MODEL

### Data

A reasonable size of sample which can at least satisfy the objectives set for the study was taken into account. During the research period, a total of 150 private fish seed hatcheries were found in the selected study areas. Considering the limited time, efforts and fund, a sample of 50 hatcheries was taken into account for the present study. It is to be noted that the scope of this research was confined with farms keeping hatcheries with brood ponds. The 50 selected sample comprised 25 hatcheries from each of the Jessore and Mymensingh districts. Hatchery operation is such an enterprise where the owners have to be involved for a specific period of the year to produce spawn. Production season for fish seed starts from March-April and continues till August-October every year. However, the survey for collection of data was conducted during November-December, 2002.

Keeping in view the objectives of the study, a preliminary survey schedule was designed for collecting data from the selected hatcheries. The questionnaire was made to accommodate information on inventory of brood fish of the farms, detailed information, such as age and average body weight of the brood fish and their productive life, quantities of inputs used and their costs, cost of tools and equipment, miscellaneous cost, production and return from spawn, and problems faced and suggestions made by the fish seed farmers. The first author himself conducted the whole survey. Data were collected from primary sources, and it was accomplished by direct interviews with the hatchery owners, mangers and technicians.

### Analytical Technique

The measurement of the productive efficiency of a farm relative to other farm or to the best practice in an industry has long been of interest to agricultural economists. Efficiency measurement has received considerable attention from both theoretical and applied economist. From a theoretical point of view, there has been a spirited exchange about the relative importance of various components of firm efficiency (Leibenstein, 1966, 1977: Comanor and Leibenstein 1969; Stigler, 1976). From an applied perspective, measuring efficiency is important because this is the first step in a process that might lead to substantial resource savings. These resource savings have important implications for both policy formation and farm management (Bravo-Ureta and Rieger 1991).

Technical efficiency refers to the ability of firm to produce maximum possible output with a minimum quantity of inputs, under a given technology. A technically efficient firm will operate on its frontier production function. Given the relationship of inputs in a particular production function, the firm is technically efficient if it produces on its outer bound production function to obtain the maximum possible output which is feasible under the current technology (Rahman *et al.* 1999).

Farrell's (1957) seminal article on efficiency measurement led to the development of several approaches to efficiency and productivity analysis. Among these the stochastic frontier production (Aigner *et al.,* 1977; Meeusen and van den Broeck, 1977) and Data Envelopment Analysis (DEA) (Charnes *et al.,* 1978) are the two principal methods. As noted by Coelli *et al.,* (1998), the stochastic frontier is considered more appropriate than DEA in agricultural applications, especially in developing countries, where the data are likely to be heavily influenced by measurement errors and the effects of weather conditions, diseases, etc. This also applies to the application of frontier techniques to fish culture. Thus following Aigner *et al.* (1977) and Meeusen and van den Broeck (1977), the stochastic frontier production with two error terms can be modeled as:

$$Y_i=f(X_i,\beta)exp(V_i-U_i) \quad (1)$$

Where $Y_i$ is the production of the i-th farm (i = 1,2,3............n), $X_i$ is a (l x k) vector of functions of input quantities applied by the i-th farm; $\beta$ is a (kxl) vector of unknown parameters to be estimated, $V_i s$ are random variables assumed to be independently and identically distributed as $N(O,\delta^2_v)$ and independent of $U_i s$ and the $U_i s$ are non-negative random variables, associated with technical inefficiency in production assumed to be independently and identically distributed as truncation (at zero) of the normal distribution with mean, $Z_i\delta$ and variance $\sigma^2_u$ (U~|N($Z_i\delta$, $\sigma^2_u$)|); $Z_i$ is a (l x m) vector of farm specific variables associated with technical inefficiency, and $\delta$ is a (m x l) vector of unknown parameters to be estimated (Sharma and Leung, 1998).

Following Battese and Coelli (1995), the technical inefficiency effects, $U_i$ in equation (l) can be expressed as:

$$U_i=Z_i\delta+W_i \quad (2)$$

Where $W_i$ are random variables, defined by the truncation of the normal distribution with zero mean and variance $\sigma^2_u$, such that the point of truncation is at $Z_i\delta$, i.e. $W_i \geq - Z_i\delta$. Beside the farm-specific variables, the $Z_i$ variables in equation (2) may also include input variables in the stochastic production frontier (1), provided that the inefficiency effects are stochastic. If $Z$

variables also include interactions between farm-specific and input variables, then a Huang and Lui (1994) non-neutral stochastic frontier is obtained.

The technical efficiency of the i-th sample farm, denoted by $TE_i$ is given by:

$$TE_i = exp\,(-U_i) = Y_i/f\,(X_i\beta)\,exp\,(V_i) = Y_i/Y_i^* \quad (3)$$

Where $Y_i^* = f(X_i\beta)\,exp\,(V_i)$ is the full efficient stochastic frontier. If $Y_i$ is equal to $Y_i^*$ then $TE_i$=1, reflects 100% efficiency. The difference between $Y_i$ and $Y_i^*$ is embedded in $U_i$ (Dey *et al.*, 2000). If $U_i = 0$, it implies that production lies on the stochastic frontier, the farm obtains its maximum attainable output given its level of input. If $U_i>0$, production lies below the frontier-an indication of inefficiency.

The maximum likelihood estimate (MLE) of the parameters of the model defined by equations (1) and (2) and the generation of farm-specific TE defined by (3) are estimated using the FRONTIER 4.1 package (Coelli, 1994). The efficiencies are estimated using a predictor that is based on the conditional expectation of *exp (-U)* (Battese and Coelli, 1993; Coelli, 1994). In the process, the variance parameters $\sigma^2_u$ and $\sigma^2_v$ are expressed in terms of the parameterization:

$$\sigma^2 = (\sigma^2_u + \sigma^2_v) \quad (4)$$

and

$$\gamma = (\sigma^2_u/\sigma^2) \quad (5)$$

The value of $\gamma$ ranges from 0 to 1 with values close to 1 indicating that random component of the inefficiency effects makes a significant contribution to the analysis of the production system (Coelli and Battese, 1996). The use of a generalized likelihood ratio test is another way of testing if inefficiency effects are absent from the model. This is used in testing the significance of the model as in the F-test in the Ordinary Least Squares (OLS) estimation. It can also be used in testing the functional form of the model (e.g. Cobb-Douglas versus translog) and is more or less equivalent of the Chow test (Green, 1990; Johnston, 1984) in OLS estimation. The generalized likelihood ratio test statistic is defined by:

$$\lambda = -2\{\,log\,[L\,(H_o)/L\,(H_1)]\} \quad (6)$$

Where $L\,(H_o)$ is the value of the likelihood function of a restricted model as specified by a null hypothesis $H_o$ and $L(H_1)$ is the value of the likelihood function of an alternative hypothesis $H_1$. The test statistic has a $\chi^2$ or mixed $\chi^2$ distribution with degrees of freedom (df) equal to the difference between the number of parameters involved in $H_o$ and $H_1$.

***Empirical Model***

Two types of functions namely, Cobb-Douglas and translog dominate the technical efficiency literature. Since, the sample number is not very high, the translog specification could not be tried. Therefore, a Cobb-Douglas function was specified. The stochastic production function for the sample fish hatchery farmers is specified as:

$$lnY_i = \beta o + \beta_1 ln(X_1) + \beta_2 ln(X_2) + \beta_3 ln(X_3) + \beta_4 ln(X_4) + \beta_5 ln(X_5) + \beta_6 ln(X_6)$$
$$+ \beta_7 X_7 + V_i - U_i \quad (7)$$

where, *In* = Natural logarithm; $Y_i$ = Fish seed (Kg); $X_1$= Pond size (decimal); $X_2$= Number. of labour (Man-days); $X_3$ = Feed (sum of rice bran, oilcake, maize, wheat bran, and fish meal measured in kg); $X_4$ = Fertilizer (sum of urea, TSP, MP and lime, measured in kg); $X_5$ = Number of brood used to produce seed (No.); $X_6$ = Proportion of quantity of hormone injected to female relative to male; $X_7$ = Region (dummy) (1=Jessore; 0 otherwise).$V_i$s and $U_i$s are as defined in equaton 1.

Following Battese & Coelli (1995), the mean of farm-specific technical inefficiency ($U_i$), $\mu_i$ *is* defined as:

$$\mu_i = \delta_0 + \delta_j Z_i \quad (8)$$

Where, $Z_1$ = Education (Years of Schooling); $Z_2$ = Experience (Years); $Z_3$ = Training (dummy, 1= trained; 0 otherwise); $Z_4$ = Salary of the operator (Taka). *$\delta_j$s are parameters of inefficiency functions to be estimated.*

## IV. RESULTS AND DISCUSSION

### Summary Statistics of the Variables Used in the Models

Table 2 displays the summary statistics of the variables used in the production frontier and inefficiency functions. It is to be mentioned here that two dummy variables (region for the production frontier and training for the inefficiency function) are not shown in the table. Spawn (fish seed), as used here in this study, refers to fry produced by the operators and sold to the nursurer to raise it up to the fingerling stage. The weight of fry was taken into consideration. The mean of the seed (fry) was 1,312 kg per farm per year ranging from a minimum of 330 kg to a maximum of 2,740 kg with a standard deviation of 612 kg. Pond area refers actually to the total water area of all the ponds under the disposal of the fish seed farms. The mean of the water area used for raising brood to is 555 decimal ranging between 100 and 1550 decimals with a standard deviation of 373 decimal.

Labuor refers to actual man-days of effort applied during the year in the production of seed including the family labuor. The average labuor man-days applied was 4,092. Feed comprises rice bran, oilcake, maize, wheat bran and fish meal; the sum of which was taken into consideration for simplicity in using the variable in the model. The specific proportion of the different items of feed were 45.04 percent for rice bran, 38.05 percent for oilcake, 2.85 percent for maize, 8.57 percent for wheat bran and 5.76 percent for fish meal. The average quantity of feed applied per year was 17,292 kg ranging between a minimum of 2200 kg and maximum of 69,429 kg.

The average fertilizer application was found to be 5,153 kg per farm per year. The fertilizer comprises 19.08 percent of Urea, 16.47 percent of TSP, 2.86 percent of MP and 61.59 percent of lime. Average number of brood fish stocked was 5,239 per farm per year ranging between 755 and 18,700. The operators were found to have average schooling of 9.64 years indicating that they are in general literate. Experience in fish seed production was, on the average, 10.44 years. Monthly average salary of the operator was Tk. 4994 ranging between Tk. 2000 and Tk. 8000.

**Table** 2. **Summary statistics of the variables used in the models.**

| Variables | Mean | Std. deviation | Minimum | Maximum | Kurtosis |
|---|---|---|---|---|---|
| Spawn (kg/farm/yr) | 1,312 | 612 | 330 | 2,740 | -0.5454 |
| Pond surface area (decimal) | 555 | 373 | 100 | 1,550 | 0.1270 |
| Labour (man-day/yr) | 4,092 | 2,137 | 1,740 | 10,445 | 2.1899 |
| Feed (kg/farm/yr) | 17,292 | 15,315 | 2,200 | 69,429 | 2.7891 |
| Fertilizer(kg/farm/yr) | 5,153 | 3,153 | 1540 | 15,790 | 2.0588 |
| Brood fish (no./farm/yr) | 5,239 | 3,928 | 755 | 18,700 | 3.6504 |
| Proportion of hormone injected to female | 0.8308 | 0.0439 | 0.6666 | 0.8888 | 2.4669 |
| Education (years of schooling) | 9.64 | 2.9606 | 0.0000 | 15.00 | 3.4098 |
| Experience in spawn production (year) | 10.44 | 4.6686 | 1 | 20 | -0.1840 |
| Monthly salary of the operator (Taka) | 4,994 | 1,361.18 | 2,000 | 8,000 | -0.3686 |

*Source: Filed Survey, 2002*

**Maximum Likelihood Estimates of the Parameters in the Stochastic Frontier and Inefficiency Effect Model**

The estimated parameter of the production frontier is presented in Table 3. The table indicates that most of the explanatory variables except the regional dummy variable in the stochastic production frontier are statistically significant. Negative sign with pond water area indicates that farms with lower size of water areas (ponds) produced more spawn. That means small ponds are more productive with respect to spawn production. The negative but significant coefficient with labor indicates that as labor man-days increase, spawn production decreases. This is not expected but not unlikely in the context where there are substantial over utilization of labor due participation of family labor, many of which are virtually redundant.

Feed has appeared with expected positive algebraic sign. It is statistically significant at 5% probability level. In fact this is a very crucial element for spawn production and has been found to have contributed positively to the spawn production. Fertilizer has been turned out to be a statistically significant contributor in the spawn production although it has a positive algebraic sign. Number of brood fish is the most important factor in spawn production. Its statistical significance at 1% level probability is evident from Table 3, indicating that the more number of brood fish the farm maintains, the higher is the spawn production.

Hormone is another major factor for producing spawn. For successful induced breeding, hormone must be applied to brood fish. In breeding season, hormone was used to stimulate matured brood fish. Consequently, vascular system of eggs gets loosen and the eggs are easily released by genital pore. Hormone was applied to both the male and female fish. Proportion of hormone dose injected to female brood relative to male appeared to be statistically significant with negative sign. This indicates that as proportionate hormone dose to female brood goes up spawn production decreases. Perhaps there are specific doses for the males and females, and when this varies there is the likelihood that spawn production is adversely affected. The mean hormone dose was 83 percent of male dose ranging from 67 percent to 89 percent. Since the mean is 83 percent, most doses are close to the upper range. It might be the situation that females and male were not properly dosed, which might have affected the spawn production. Induced breeding of fish in the hatchery is a very technical practice and requires professional skills and appropriate hatchery installations (Hussain, 2000). The technicians of the farms dealing with induced breeding may not have that level of professional skills and therefore, such results are not unlikely. Since the production frontier is of Cobb-Douglas type, the estimated coefficients are also elasticities of production.

**Table 3. Maximum likelihood estimate of stochastic Cobb-Douglas production frontier and technical inefficiency model for hatchery operators.**

| Variables | Parameter | Coefficient | t-ratio |
|---|---|---|---|
| Stochastic Frontier: | | | |
| Constant | $\beta_0$ | 6.1334*** | 15.6442 |
| Ln (water area) | $\beta_1$ | -0.1239* | -1.88741 |
| Ln (human labour) | $\beta_2$ | -0.2018** | -2.1183 |
| Ln (feed) | $\beta_3$ | 0.1494** | 2.1599 |
| Ln (fertilizer) | $\beta_4$ | 0.0444 | 0.7842 |
| Ln (no. of brood fish) | $\beta_5$ | 0.1985*** | 4.0141 |
| Ln (proportion of hormone given to female brood relative to male) | $\beta_6$ | -2.9848*** | -3.2639 |
| Regional dummy | $\beta_7$ | -0.0877 | -1.1489 |
| Log-likelihood value | | -30.5478 | |
| Mean technical efficiency | | 61.00% | |
| Variance Parameter: | | | |
| Sigma square | $\sigma^2$ | 0.4789*** | 4.0595 |
| Gamma | $\gamma$ | 0.9999*** | 6422452.8 |
| Inefficiency Function: | | | |
| Constant | $\delta_0$ | 1.6132* | 1.8418 |
| Education | $\delta_1$ | 0.0999 | 1.6737 |
| Experience | $\delta_2$ | -0.0530 | -1.4205 |
| No. of training received | $\delta_3$ | -0.5253* | -1.8304 |
| Salary of the operator | $\delta_4$ | -0.00037*** | -3.1377 |

*** significant at 1% level, ** significant at 5% level, *significant at 10% level

The linear inefficiency function have 4 variables. Three out of four explanatory variables of the inefficiency function are significant with appropriate negative signs. The constant of the inefficiency function is also significant at 10% level. Education, measured in terms of years of schooling, does not appear to be a factor contributing to the reduction of inefficiency. In fact what is needed in the reduction of inefficiency is the technical skill which may be lacking. Experience gathered over the years is perhaps a factor contributing to the reduction of inefficiency. Although it is not statistically significant but it does have an appropriate algebraic sign. Training improves skills, and the result supports that professional training reduces inefficiency in the spawn production. Salary of the concerned persons is a significant factor in reducing inefficiency. It is quite likely that skilled operators are highly paid as well as motivated and their involvement in the farm help reduce technical inefficiency. The variance parameters are also found to be highly statistically significant.

**Hypotheses Tests**

Results of the hypotheses tests are presented in table 4. Two relevant null hypotheses tests namely, non-existence of inefficiency effect and non-existence of the effects of explanatory variables in the inefficiency function were conducted first. In addition, tests concerning the effect of each of the variables in the inefficiency functions were also conducted. The format for the null hypothesis: non-existence of the inefficiency effect is $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$. The test statistics was estimated to be 24.23 suggesting that the null hypothesis was rejected. The rejection of the null hypothesis supports the existence of inefficiency effect on the spawn production of the sampled hatchery operators. This implies that the traditional average response function is not an adequate representation for spawn production, given the stochastic frontier and inefficiency models defined in equations (7) and (8). The $\gamma$ (gamma) parameter, shown in table 4, is very close to one and highly significant suggesting that there exists technical inefficiency effect in the stochastic frontier model. That is, the traditional production function, with no technical inefficiency effects, is not an adequate representation of the data.

The hypothesis relating to whether technical inefficiency effects have the same truncated normal distribution was tested imposing $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$. The test statistics was found to be 14.39, which is much higher than the critical value supporting the rejection of the null hypothesis. It can therefore, be concluded that the inefficiency effects are significantly influenced by education, experience, training and monthly salary of the operators.

Only one test concerning the effect of hormone dose applied to female brood relative to male brood on the production of spawn was conducted for the production frontier. The hypothesis tested was $\beta_6 = 0$ i.e., proportion of hormone dose applied to female brood relative to male brood has no effect on the production of spawn. The test statistics was found to be 22.09 which is highly significant at 1% level supporting the fact that the proportion of hormone dose applied to female brood significantly influence the production of spawn. Therefore, it can be concluded that this dose has to be appropriate if the production of spawn is to be promoted. Proper investigation on this must be made so that proper doses of hormone are given to male and female brood to maximize the production of spawn for seed production.

**Table 4. Generalized likelihood ratio test of null hypotheses for parameters of the inefficiency function.**

| Test of null hypotheses | Log-likelihood value under null hypotheses | Test statistics | Degrees of freedom | Critical values at 95% | Conclusion |
|---|---|---|---|---|---|
| No existence of inefficiency effect ($\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$) | -18.43 | 24.23 | 6 | 13.40* | Reject $H_0$ |
| No effect of education, experience, training and salary ($\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$) | -23.35 | 14.39 | 4 | 9.49 | Reject $H_0$ |
| No effect of hormone ($\beta_6 = 0$) | -19.50 | 22.09 | 1 | 3.84 | Reject $H_0$ |
| No effect of education on inefficiency ($\delta_1 = 0$) | -20.12 | 20.86 | 1 | 3.84 | Reject $H_0$ |
| No effect of experience on inefficiency($\delta_2 = 0$) | -19.74 | 21.62 | 1 | 3.84 | Reject $H_0$ |
| No effect of number of training on inefficiency($\delta_2 = 0$) | -22.43 | 16.23 | 1 | 3.84 | Reject $H_0$ |
| No effect of monthly salary of operator on inefficiency ($\delta_4 = 0$) | -24.64 | 11.82 | 1 | 3.84 | Reject $H_0$ |

* The correct critical values for the null hypothesis of no inefficiency effects are obtained from Kodde and Palm (1986)

The null hypothesis ($\delta_1 = 0$) implies that education has no effect on the inefficiency. This hypothesis is rejected and support that education has significant effect on the inefficiency. The null hypotheses that experience, training and monthly salary of the operators have no effect on efficiency were also rejected. Moreover, signs of each of these variables were negative indicating that they significantly reduce the inefficiency.

**Technical Efficiency and Its Distribution**

The distribution of technical efficiency scores relative to the best practice frontier scores are presented in Table 5. The mean technical efficiency was found to be 61 percent for the hatchery operators as far as fish seed production is concerned. Technical efficiency scores were not found to be skewed towards higher or lower levels of efficiency, where a score of 1 lies on the frontier, with concentrations in the 20$^{th}$, 30$^{th}$, 80$^{th}$ and 90$^{th}$ percentiles. This indicates that the hatchery operators operate at a moderately low level of efficiency. A significant level of inefficiency exists. Our test concerning existence of inefficiency also conforms to the existence of moderate level of efficiency. The distribution of the technical scores as shown in Table 5 reveals that, although the mean efficiency is 61 percent, it ranged from a minimum of 16 percent (in the interval 11-20%) to a maximum of 99 percent (interval 91-100). Efficiency scores are to some extent concentrated in upper tail (91-100%). Thirty four percent of the operators have TE higher than 80 percent. On the other hand 32 percent are operating between 21 to 40 percent TE level. Figure 1 shows the frequency distribution of technical efficiency scores.

**Table 5. Frequency distribution of technical efficiency scores.**

| Efficiency interval (%) | Frequency (no. of farm) | Percentage of farm |
|---|---|---|
| 0 - 10 | 0 | 0 |
| 11 - 20 | 1 | 2 |
| 21 - 30 | 7 | 14 |
| 31 - 40 | 9 | 18 |
| 41 - 50 | 2 | 4 |
| 51 - 60 | 6 | 12 |
| 61 - 70 | 5 | 10 |
| 71 - 80 | 3 | 6 |
| 81 - 90 | 7 | 14 |
| 91 -100 | 10 | 20 |

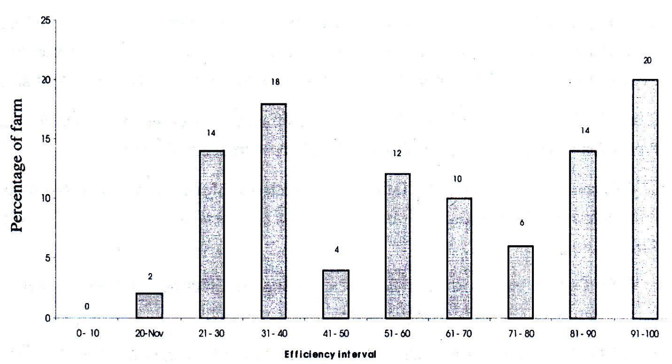


**Fig 1 Frequency districtuion of technical efficiency scores**

## V. CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

Considerable technical inefficiencies exist in fish seed production system practised in the hatcheries and FSMFs of Bangladesh. The FSMFs operate 39% below the potential frontier production level with the given inputs and production technology. Thus the hatcheries and FSMFs are not in a position to tap the benefits of the development of seed production technology. Education and experience prove to be significant contributor to influence technical efficiency, thus these need to be made effective for the hatchery /FSMF operators especially those working in the area of induced breeding. Skills of these people need to be developed through training and practial demonstration. Of course the proper physical infrastructure need to be established alongside. Since, the overall technical efficiency level is even less than two-third, there is no justification at present to further develop seed production technology. What is needed more is the development of skill of the technicians and operators of the FSMFs/hatcheries to enable them to achieve full potential of the fish seed production. Government should oversee the existing skills of the people behind the hatcheries and FSMFs, make an inventory of the training needs and infrastructures qualities and recommend accordingly for training of the people. Quality of existing infrastructures including broods being used for induced breeding should also be overseen.

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