Diversification economies and efficiencies in a ‘blue-green revolution’ combination: a case study of prawn-carp-rice farming in the ‘gher’ system in Bangladesh

Rahman, S. ORCID: https://orcid.org/0000-0002-0391-6191, Barmon, B. K. and Ahmed, N. (2011) Diversification economies and efficiencies in a ‘blue-green revolution’ combination: a case study of prawn-carp-rice farming in the ‘gher’ system in Bangladesh. Aquaculture International, 19 (4). pp. 665-682. ISSN 1573-143X doi: https://doi.org/10.1007/s10499-010-9382-z Available at https://centaur.reading.ac.uk/107873/

To link to this article DOI: http://dx.doi.org/10.1007/s10499-010-9382-z

Publisher: Springer

Revised Version: AQUI1068

Diversification economies and efficiencies in a 'Blue-Green Revolution' combination: a case study of prawn-fish-rice farming in the '*gher*' system in Bangladesh

Sanzidur Rahman

School of Geography, Earth and Environmental Sciences, University of Plymouth, UK

Basanta K. Barmon

Department of Economics, East West University, Dhaka, Bangladesh

Nesar Ahmed

Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, Bangladesh

Address for correspondence

Dr. Sanzidur Rahman

Associate Professor in Rural Development

School of Geography, Earth and Environmental Sciences

University of Plymouth

Drake Circus

Plymouth, PL4 8AA

Phone: +44-1752-585911

Fax: +44-1752-585998

E-mail: srahman@plymouth.ac.uk

September 2010

Diversification economies and efficiencies in a ‘Blue-Green Revolution’ combination: a case study of prawn-carp-rice farming in the ‘*gher*’ system in Bangladesh

ABSTRACT

‘Gher’ farming is a unique system that incorporates the joint operation of three enterprises: freshwater prawn, fish and HYV rice, and is expanding rapidly in the coastal regions of Bangladesh. In this paper we evaluate the performance of this unique system in terms of the existence of diversification economies (amongst the three integrated enterprises), scale economies and technical efficiency using a stochastic input-distance function approach on a sample of gher farmers. The results reveal evidence of a diversification economy in the rice-carp combination. Economies of scale exist in the ‘gher’ farming system. The level of technical efficiency is estimated at 68% implying that a substantial 47% [(100-68)/68] of potential output can be recovered by removing inefficiency. Significant efficiency gains are made from diversification amongst these enterprises. Also, the education of farmers and the female labour input significantly improve efficiency while larger operation size reduces efficiency. The key policy implication is that the diversification of enterprises, particularly the rice-carp combination, is beneficial and should be promoted. Also investment in education and creation of a hired labour market for females would improve technical efficiency.

JEL classification: O33; Q18; C21

Key Words: Diversification economies, technical efficiency, gher, blue-green revolution, Bangladesh

1. Introduction

The economy of Bangladesh is largely dependent on crop agriculture although aquaculture is gaining in importance in recent years. Bangladesh is considered as one of the most suitable countries in the world for freshwater prawn (*Macrobrachium rosenbergii*) farming, because of its favourable resources and agro-climatic conditions. A sub-tropical climate and a vast area of shallow water bodies provide a unique opportunity for freshwater prawn production (Ahmed et al., 2008a). Within the overall agro-based economy in Bangladesh, *M. rosenbergii* farming is currently one of the most important sectors. During the last three decades, its development has attracted considerable attention due to export potential. The freshwater prawn is a highly valued product for international markets; almost all prawns are therefore exported, particularly to the USA, Europe and Japan (Ahmed et al., 2009; Islam, 2008). In 2007-08, Bangladesh exported 49,317 tons of prawn and shrimp[1] valued at US$415 million, of which 30% was contributed by prawn (Khandaker, 2009). Prawn marketing potentially provides economic returns and social benefits to thousands of rural poor.

Table 1 shows the expansion of prawn/shrimp farming in Bangladesh, confirming that the area under coastal prawn/shrimp farming has increased almost three fold in Khulna region and one and a half fold in the Chittagong region between 1986 and 2007. Productivity has also improved productivity currently estimated at 398 kg/ha/year and 452 kg/ha/year in the Chittagong and Khulna regions, respectively. These two regions cover approximately 750 km of coastline in Bangladesh and contribute 97% of total prawn/shrimp production (Table 1).

The total area under prawn cultivation, in particular, in Bangladesh is estimated to be around 50,000 ha (Khondaker, 2009). Most prawn farms (71%) are located in southwest Bangladesh, mainly in the Bagerhat, Khulna and Satkhira districts, with the remainder in the southeast region (Ahmed et al., 2008a). The practice of small-scale prawn farming in rice fields is widespread in southwest Bangladesh due to the availability of wild postlarvae and low-lying rice fields, a warm climate, fertile soil, and cheap and abundant labour. The most spectacular development of prawn farming has taken place in the Bagerhat district, where thousands of farmers have converted their rice fields to prawn farms to accommodate the

---

[1] The term ‘shrimp’ is used for species in the family *penaeidae*.

profitable prawn culture. The innovation of prawn farming in rice fields, combined with high prices for prawn in the international market, and rice for household consumption, has led increasing numbers of farmers to convert their rice fields to prawn farms (Ahmed et al., 2010).

A number of studies have been conducted on prawn farming in Bangladesh, including a history of prawn farming (Ahmed et al., 2008a), prawn farming in gher systems (Ahmed et al., 2008b; Barmon et al., 2008), a livelihood analysis of prawn farmers and associated groups (Ahmed et al., 2008c), economic returns to prawn and shrimp farming (Islam et al., 2005), agrarian change and economic transformation (Ito, 2002; 2004), and prawn and shrimp marketing (Ahmed et al., 2009; Islam, 2008). However, there is a lack of information on the production performance of prawn farming in Bangladesh, which is the major source of expansion of the prawn/shrimp industry portrayed in Table 1. To our knowledge, only a couple of studies exist on the performance of shrimp farming alone (e.g., Shang et al., 1998; and Rashid and Chen, 2002) and none for prawn farming. For example, technical efficiency[2] of shrimp farming in Bangladesh is quite low estimated at only 11% and 48% in extensive and semi-intensive farming respectively, when compared with their most efficient peers within the Asian region (Shang et al., 1998). Rashid and Chen (2002) estimated technical efficiency in shrimp farming at 82%, 85% and 93% in extensive, improved extensive and semi-intensive farming methods, respectively in Bangladesh. Nevertheless, we postulate that the past examination of production performance in Bangladeshi prawn/shrimp farming is an underestimate and flawed because farmers practice prawn culture within a unique system called 'gher' farming which incorporates three enterprises that are integrated, namely, freshwater prawn, fish (mainly Indian major carps and exotic carps), and High Yielding

---

[2] Technical efficiency is defined as the ability of a firm to obtain maximum possible output from a given set of inputs.

Variety (HYV) rice, over a one year cycle. Therefore, failure to identify the integrated nature of this farming system has resulted in painting a gloomy picture of the prospects for prawn/shrimp farming in Bangladesh (e.g., Shang et al., 1998). The evidence base for our argument is clear from Table 1, which shows that the production of other fish (mainly carp) is also reported in conjunction with prawn/shrimp production for the same level of cultured area. Therefore, it is essential to analyze the production performance of 'gher' farming as a system which could shed light on the observed consistent increase in area, production and productivity of prawn and associated fish from these Bangladeshi coastal farms as seen in Table 1. Also, there is a need to systematically examine whether any economies of diversification[3] and efficiencies exist in such a system which can potentially be replicated in other regions of the country that are not near the coastline.

Given this backdrop, the present study sets out to examine: (a) the profitability of 'gher' farming as a system; (b) the existence of economies of diversification among the three enterprises that encompass the 'gher' farming system; and (c) the impact of diversification of enterprises on technical efficiency.

The paper proceeds as follows: section 2 briefly describes the 'gher' farming system; section 3 describes the analytical framework, study area and the data; section 4 presents the results; and section 5 concludes and draws policy implications.

2. The 'gher' farming system

The term 'gher' refers to the modification of a paddy field to enable the operation of three enterprises: prawn (principal enterprise), fish, and HYV rice. The middle of the 'gher' is surrounded by high and wide dikes with canals dug at the inner periphery of the dikes. The

---

[3] The term 'diversification' here refers to the allocation of resources to a variety of enterprises, the outcome of which are not closely related (Coelli and Fleming, 2004). In this sense, economies of diversification or diversification economies exist if a particular firm can produce two outputs by allocating relatively less resources than two separate firms specializing in the production of two individual outputs would require.

whole area of the ‘gher’ is filled with rain-water during the monsoon season, specifically from June to December, and closely resembles a typical pond. The ‘gher’ becomes dry naturally from January to April except the canals (see Figure 1).

A typical ‘gher’ cycle begins in June when farmers release freshwater prawn (*M. rosenbergii*) postlarvae into the ‘gher’. Farmers use lime during ‘gher’ preparation to reduce soil acidity. During the growing period, farmers provide supplementary feed to the prawn. Traditionally, snail meat was used as prawn feed, but nowadays farmers use a wide range of homemade and commercially available supplementary feeds to increase production. The system is labour intensive. Before releasing prawn postlarvae, farmers repair the ‘gher’ dikes and trenches almost annually. The carp fingerlings were also released into the ‘gher’ during May-June and are cultured for nine months or so (as long as sufficient water is retained in the ‘gher’). Usually, no specific supplementary feed is provided for the carp. Carps share the feed supplied to the prawns. Between January to April, farmers grow HYV *Boro* rice on the land inside the ‘gher’, which is irrigated by water from the inside canals using either traditional methods (swing basket) and/or pumps.

3. Methodology

3.1 Data and the study area

This study is based on farm-level cross sectional data for the crop year 2006 collected from Bilpabla located in southern Bangladesh[4]. Bilpabla is one of the typical villages in the Dumuria sub-district of the Khulna District and is located 310 km south from the capital Dhaka (Figure 2). The village is divided by a small river and the households are mainly located on both sides of the river. The demographic characteristics of the village are very similar to other villages where ‘gher’ farming is practiced. A total of 90 ‘gher’ farmers were

---

[4] Bilpabla village was selected purposively because the farmers have long years of experience of the ‘gher’ farming system.

randomly selected. The survey was conducted for a period of six months from November 2006 to April 2007. Questionnaire interviews with gher farmers were preceded by preparation and testing of the questionnaire and the use of enumerators to fill in the questionnaires.

3.2 Analytical framework

To examine the existence of diversification economies and diversification efficiencies, a multi-output, multi-input production technology specification is required as opposed to the commonly used single-output, multi-input production technology. The use of a distance function approach (either output-orientated or input-orientated) circumvents this problem and can be analyzed using either parametric or non-parametric methods. Also, the main advantage of a distance function approach is that the production frontier can be estimated without assuming separability of inputs and outputs (Kumbhakar et al., 2007). We have selected the use of an input-orientated stochastic distance function to address these research questions. This is because, in an economy like Bangladesh, on the one hand, inputs are highly scarce, particularly the land input, and on the other hand, farmers are often constrained by cash/credit (Rahman, 2009). Therefore, it is logical to assume that cost minimization is the prime concern.

We begin by defining the production technology of the farm using the input set, L(y), which represents the set of all the input vectors, $x \in R_+^K$, which can produce the output vector $y \in R_+^M$. That is,

$$L(y) = \{x \in R_+^K : x\, can\; produce\; y\} \qquad (1)$$

The input-distance function is then defined on the input set, L(y), as

$$D_I(x, y) = \max\{\rho : (x/\rho) \in L(y)\} \qquad (2)$$

$D_I(x,y)$ is non-decreasing, positively linearly homogenous and concave in *x*, and increasing in *y*. The distance function, $D_I(x,y)$, will take a value which is greater than or equal to one if the input vector, x, is an element of the feasible input set, $L(y)$. That is, $D_I(x,y) \geq 1$ if $x \in L(y)$. Furthermore, the distance function will take a value of unity if x is located on the inner boundary of the input set.

3.3 Economies of diversification and diversification efficiencies

A number of performance measures can be developed from an input distance function. We adopt a measure of economies of diversification developed by Coelli and Fleming (2004) also applied by Rahman (2009) which, in principle, can be conceived of as the lower-bound estimate of the traditional cost function measure of scope economies. In this formulation, the second cross partial derivative of the input distance function, with respect to output, needs to be positive, to provide evidence of economies of diversification. That is, the economies of diversification exist between outputs *i* and *j* if (Coelli and Fleming, 2004):

$$\frac{\partial^2 D}{\partial Y_i \partial Y_j} > 0, \qquad i \neq j, \quad i, j = 1,....m. \qquad (3)$$

In addition to the examination of diversification economies, another key question of interest is to investigate is whether farming inefficiencies are related to the degree of diversification (or specialization) of enterprises. Specialization of farming activity may lead to lower inefficiency or vice versa. Specialization in production leads to efficiency gains in the division of labour and management of resources (Coelli and Fleming, 2004). Diversification efficiency, which works in the opposite direction to specialization efficiencies, may be derived from intimate knowledge of farmers' yet uncertain production environment and the ability to adjust their labour and other resources to various farming activities.

An Ogive (pointed arch) index, which provides a measure of concentration of output shares of the enterprises, is used to represent the specialization variable (Coelli and Fleming, 2004). The Ogive index is defined as:

$$Ogive = \sum_{n=1}^{N} \frac{(Y_n - (1/N))^2}{1/N} \qquad (4)$$

where N is the total number of production enterprises under consideration and Y is the share of the *n*th enterprise to total output (measured in terms of gross value of output). An Ogive value of 1/N indicates perfect diversification of output among enterprises.

3.4 Other factors explaining technical efficiency

In addition to variables representing diversification (or specialization) of enterprises, a number of other explanatory factors representing farmers' socio-economic circumstances may affect efficiency. These are: the 'gher' area of the farmer, farmers' education, farming experience (proxied by age of the farmer), dependency ratio (family size/number of working members), and share of female labour in total labour. Choice of these variables is based on the existing literature and the justification for their inclusion is briefly discussed as follows.

In Bangladesh, land ownership serves as a surrogate for a number of factors as it is a major source of wealth and influences crop production (Hossain et al., 1990). The size-productivity relationship in Bangladesh varies across regions depending on the level of technological development and environmental opportunities. The relationship is positive in technologically advanced regions, whereas the classic inverse relationship still exists in backward areas (Toufique, 2001). We included the 'amount of 'gher' area operated' to test whether size of operation in this farming system influences technical efficiency. This is because Islam et al. (2005) reported that gher size has an influence on total production with smaller ghers managing to yield higher production.

Use of the education level of farmer as a technical efficiency shifter is fairly common (e.g., Asadullah and Rahman, 2009; Wadud and White, 2000; Wang et al., 1996). The education variable is also used as a surrogate for a number of factors. At the technical level, access to information as well as capacity to understand the technical aspects related to production is expected to improve with education, thereby, influencing technical efficiency. The justification for including age is straightforward as older, and hence experienced, farmers are more likely to be wiser in decisions regarding the use and allocation of scarce inputs (e.g., Coelli and Fleming, 2004; Llewelyn and Williams, 1996).

According to the Chayanovian theory of the peasant economy, higher subsistence pressure increases the tendency to adopt new technology and this has been found to be the case in Bangladesh (Hossain et al., 1990). The subsistence pressure variable (defined as the dependency ratio = family size per household/number of working members) was incorporated to test whether it influences technical efficiency as well (e.g., Wang et al., 1996; Ali et al., 1994).

A commonly held view on women's involvement in agricultural production in Bangladesh is that they are involved only in the post-harvest processing of crops, thereby, underestimating their contribution to national economy (Rahman, 2010; 2000). In fact, the share of women in labour use ranges between 11–18% in foodgrain (rice and wheat) production and 14–48% in non-cereal (highest for vegetables) production in Bangladesh (Rahman, 2000). In the ‘gher’ farming system, female labour use is also similar to foodgrain production (see Table 3). An argument often used against women farmers is that they are less efficient as compared to their male counterparts (FAO, 1985). Whether women are more or less efficient than men in farming is a hotly debated issue and results vary (Adesina and Djato, 1997). In recent years, a few studies have analyzed influence of women’s input on technical efficiency only and the results are mixed. For example, Bozoglu and Ceyhan (2007) concluded that women’s participation in farm decision making significantly improves technical efficiency in vegetable farming in Samsun province in Turkey, whereas Hasnah et al. (2004) did not find any significant influence of the share of female labour input as a technical efficiency shifter in the oil palm sector in West Sumatra, Indonesia. However, Rahman (2010) found significant influence of female labour input share on technical efficiency in crop farming in Bangladesh. In this study, following Rahman (2010), we have incorporated female labour input as an independent variable in the production frontier function and the share of female labour input in total labour as the technical efficiency shifter to account for the role played by female labour in both productivity as well as technical efficiency.

3.5 The empirical model

A multi-output, multi-input stochastic distance function was used to compute the farm specific technical efficiency index. The empirical model is specified using a translog stochastic input distance function allowing for interactions. However, in order to preserve the degrees of freedom, we have allowed all input interactions and output interactions but did not allow interactions between inputs and outputs[5]. All the variables were mean-corrected prior to estimation, so that the coefficients of the first-order terms can be directly interpreted as elasticities or marginal effects. The (partial) translog stochastic input distance function, dropping the j^{th} subscript for individual farms, is specified as:

$$\begin{aligned}\ln d &= \alpha_0 + \sum_{i=1}^{4} \alpha_i \ln X_i + \frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4} \alpha_{ij} \ln X_i \ln X_j + \\ &\sum_{k=1}^{3} \beta_k \ln Y_k + \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3} \beta_{kl} \ln Y_k \ln Y_l \qquad (5)\end{aligned}$$

where Xs are inputs and Ys are outputs. The four inputs used in the analyses are: X_1 = ‘gher’ area (ha), X_2 = amount of male labour (family supplied + hired) input (person days), X_3 = amount of female labour (family supplied + hired) input (person-days), and X_4 = purchased inputs (Bangladeshi taka). The three outputs are: Y_1 = prawn (kg), Y_2 = fish (kg), and Y_3 = value of HYV rice + straw (Bangladeshi taka).

---

[5] Coelli and Fleming (2004) applied a more restrictive translog specification allowing for only output interactions (presumably to preserve degrees of freedom) and called it a (partial) translog model.

Following Coelli and Perelman (1999), we set $-\ln d = v - u$, and impose the restriction required for homogeneity of degree +1 in inputs $(\sum_{i=1}^{4} \alpha_i = 1)$ to obtain the estimating form of the stochastic input distance function (i.e., normalizing the input vectors by any one of the inputs, specifically the land input X_1):

$$-\ln X_1 = \alpha_0 + \sum_{i=2}^{4} \alpha_i \ln\left(\frac{X_i}{X_1}\right) + \frac{1}{2}\sum_{i=2}^{4}\sum_{j=2}^{4} \alpha_{ij} \ln\left(\frac{X_i}{X_1}\right) \ln\left(\frac{X_j}{X_1}\right) + \sum_{k=1}^{3} \beta_k \ln Y$$
$$+ \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3} \beta_{kl} \ln Y_k \ln Y_l + v - u \qquad (6)$$

where the *v*s are assumed to be independently and identically distributed with mean zero and variance, σ_u^2 ; and the *u*s are technical efficiency effects that are assumed to be identically distributed such that *u* is defined by the truncation at zero of the normal distribution with unknown variance, σ_u^2, and unknown mean, μ, defined by:

$$\mu = \delta_0 + \sum_{m=1}^{6} \delta_m Z_m \qquad (6)$$

where Z_1 = amount of 'gher' area (ha), Z_2 = education of farmer (years of completed schooling), Z_3 = experience (age) of farmer (years), Z_4 = dependency ratio (number), Z_5 = share of female labour input (proportion), and Z_6 = Ogive index of output concentration (number).

We follow Battese and Corra (1977) in replacing the variance parameters, σ_v^2 and σ_u^2, with $\gamma = \frac{\sigma_u^2}{(\sigma_v^2 + \sigma_u^2)}$ and $\sigma_s^2 = \sigma_v^2 + \sigma_u^2$ in the estimating model. The input distances are predicted as (Coelli and Perelman, 1999): $d = E[\exp(u) \mid e]$, where $e = v - u$. The inverse of these input distances *(d)* are the technical efficiency scores of each individual farm, which have a feasible range from zero to unity, with unity being fully efficient (Coelli and Fleming, 2004). Estimates of the parameters of the model were obtained using maximum likelihood procedures, detailed by Coelli and Perelman (1999). STATA Software Version 8 was used for the analyses (Stata Corp, 2003).

4. Results

4.1 Profitability and factor shares in the 'gher' farming system

Table 2 presents factor shares and profitability per hectare from the prawn-carp enterprise as well as the HYV Boro rice enterprise. It is clear from Table 2 that prawn enterprise is the most capital intensive, whereas the carp enterprise incurs only a fraction of the costs. The purchased inputs account for 23% of gross returns and labour accounts for another 20% in prawn-carp culture. Factor shares of Boro rice are lower for both categories and are far less capital intensive. Overall, the profitability of HYV rice is higher (69.2%) than the prawn-carp enterprise (56.7%), although in actual financial terms, prawn culture generates 7.9 times more return per hectare than HYV Boro rice (Table 2). The fish enterprise, which costs almost nothing, contributes a substantial 5.3% to gross returns and in actual financial terms is equivalent to 60% of the gross returns derived from the HYV Boro rice enterprise, and therefore, should not be ignored when examining farm profitability. This partly explains the rising trend of prawn/shrimp area and the joint production of prawn/shrimp and carp observed in Table 1.

4.2 Productivity of the 'gher' farming system

Prior to the presentation of the model results, we provide a summary of the key characteristics of the sampled farmers (Table 3). The average 'gher' size is 0.83 ha; the average share of women labour input is 11%, the average level of education is 6.83 years of schooling; the average age is 41 years; and the dependency ratio is 1.84. The computed Ogive index of output concentration ranges from 0.82 to 1.56 with a mean score of 1.21 indicating the presence of diversification.

The results of the maximum likelihood estimation (MLE) of the stochastic input distance function model are presented in Table 4. Two sets of hypotheses were tested using the Likelihood Ratio tests. First, we tested for the presence of inefficiencies in the model. The parameter γ is the ratio of error variances from Eq. (6). Thus, γ is defined between zero and one, where if $\gamma = 0$, technical inefficiency is not present, and where $\gamma = 1$, there is no random noise. The test of significance of the inefficiencies in the model ($H_0: \gamma = \mu = 0$) was rejected at the 1% level of significance, indicating that the MLE is a significant improvement over an Ordinary Least Squares (OLS) specification and inefficiencies are present in the model. The calculated value of the test statistic is 81.93, which is greater than the critical value obtained from Table 1 of Kodde and Palm (1986) with three restrictions. Second, we tested the joint significance of all the variables including the crop diversification index and the null hypothesis ($H_0: \delta_m = 0$ for all m) was rejected at the 1% level of significance. The calculated value of the test statistic is 134.18, which is greater than the critical value of χ^2 with 6 restrictions, implying that the inclusion of these variables to explain inefficiency is justified.

Fifty percent of the estimated coefficients are significantly different from zero at the 10% level at least. The signs of the coefficients on the first order terms of the input and output variables are consistent with theory. For example, a positive coefficient on any input variable implies substitutability of that input with ‘gher’ area. On the other hand, a negative coefficient on any output variable implies that a reduction in ‘gher’ area is positively associated with a reduction in that output. The coefficients on a number of interaction variables (second order terms) are also significantly different from zero, thereby, confirming non-linearities in the production process, and hence, justify the use of flexible translog specification. It should be noted that in a flexible translog function model with a large number of inputs and outputs, violation of the regularity condition in some inputs and outputs are unavoidable. Table 4 shows that the female labour input violates the expected regularity conditions (i.e., a positive sign on the input coefficients and a negative sign on the output coefficients). However, since the value of the coefficient on this variable is not significantly different from zero, it may not be the true relationship. Another point to note is that the results presented in Table 4 are true at the point of approximation of the translog function.

The sum of the coefficients on the three output variables (prawn, carp, and HYV rice) is 0.46 (Table 4). The inverse of this figure (2.18) provides a measure of ray scale economies[6] (at the sample means), suggesting increasing returns to scale. The implication is that the farmers are likely to benefit from significant economies of scale (Coelli and Fleming, 2004; Rahman, 2009).

4.3 Economies of diversification

Following Coelli and Fleming (2004), we calculated the measure of diversification economies (defined in Eq. 3) using the coefficient estimates reported in Table 4 for each pair of crop enterprises (outputs) at the mean values of the sample data. The result of this exercise is presented in Table 5. We found evidence of significant economies of diversification only between the carp and HYV rice combination, although we would have expected a similar relationship between prawn and rice. Since, a double log specification is used to compute these diversification economies, the coefficients can be read as diversification elasticities. For example, the diversification economy between carp and HYV rice is estimated at 0.10. The implication is that a one percent increase in carp production will reduce the marginal use of inputs for producing HYV rice by 0.10%. The mechanism of this economy is perhaps a higher supply of nutrients from the carp in the form of droppings which results in less use of inorganic fertilizers for rice production, hence economizing on inputs due to diversification.

---

[6] Scale economies exist if a firm can produce a proportionately higher level of output relative to input proportions as firm size expands.

Barmon et al. (2008) noted that fertilizer use is significantly lower in rice production under gher farming as compared to year round HYV rice farming.

4.4 Diversification efficiencies

The technical efficiency scores range from 8% to 99%, with a mean score of 68% (Table 6). The implication is that 47% [(100-68)/68] of the potential output can be recovered by eliminating technical inefficiency which is substantial and could improve the competitiveness of the Bangladeshi prawn industry. Our estimates of technical efficiency are substantially higher than those reported by Shang et al. (1998) for shrimp farming in Bangladesh, thereby confirming our previous argument that an analysis of the production performance of Bangladeshi prawn/shrimp farming should be undertaken within a systems framework[7]. Martinez-Cordero and Leung (2004) reported a very high level but declining rate of technical efficiency of shrimp farming in Mexico over a 4-year period, estimated at 91.7% in 1994 and falling to 83.7% in 1998; which is comparable to other regions of Asia, such as the Philippines and Thailand (e.g., Shang et al., 1998). Technical efficiency of carp culture in the Asian region is, however, range from 42% in all farm types in Malaysia (Iinuma et al., 1999) as well as in extensive farms in Vietnam to 93% among intensive farms in China (Dey et al., 2005). Our estimate of technical efficiency is quite similar to the estimates of average agricultural farms (sometimes including livestock/dairy farms) in Bangladesh and/or elsewhere in the world (e.g., Bravo et al., 2007; Coelli et al., 2002, Wadud and White, 2000).

The distribution of the efficiency score is similar at the middle and lower end of the efficiency spectrum. About 21% of the farmers are producing at an efficiency level of less than 50%. However, 42% of the farmers are producing at an efficiency level of 80% and

---

[7] Brackish water shrimp farming is also produced within a ‘gher’ system, where the associated enterprise is salt farming (sea-salt to be precise).

higher, which is encouraging. Observation of such a wide inefficiency spectrum is not surprising and is similar to those reported in the literature (e.g., Bravo-Ureta et al., 2007; Rahman, 2003; Wang et al., 1996; Ali et al., 1994).

The lower panel of Table 4 provides the results of the inefficiency effects model. It is clear from Table 4 that significant diversification efficiency exists in the 'gher' farming system, as expected. The positive coefficient on the Ogive index indicates that technical inefficiency is positively associated with specialization, which implies that the diversification of enterprises, therefore, significantly improves technical efficiency. This result is consistent with Rahman (2009) and Coelli and Fleming (2004) but not with Haji (2007) and Llewelyn and Williams (1996).

Education significantly improves technical efficiency, consistent with Asadullah and Rahman (2009) and Sharif and Dar (1996) for Bangladeshi farms. The contribution of female labour input significantly improves technical efficiency, consistent with Rahman (2010) and Bozoglu and Ceyhan (2007) but not with Hasnah et al. (2004). Large 'gher' farms seem to be relatively technically inefficient, as indicated by the significantly positive coefficient on the 'gher' area variable, which is consistent with the existing literature (e.g., Ali et al., 1994).

5. Conclusions and policy implications

The aim of this study was to examine whether diversification economies and efficiencies exist in the 'gher' farming system in Bangladesh that has experienced remarkable growth over the past two decades in terms of area, production and productivity. The overall profitability of the 'gher' farming system is substantially higher when compared with profitability from only prawn/shrimp farming, as reported in the literature. We find strong evidence of diversification economies in one combination of enterprises, the carp and HYV rice combination. The economy of diversification perhaps is realized in two ways: (a) by the effective use of household labour in different periods and avoiding bottlenecks in labour usage; and (b) by using less purchased inputs, particularly fertilizers and irrigation. This is because the unused feed supplied to the ‘gher’ for prawn-carp serves as fertilizer; and irrigation is provided from water retained in the canals which is a substantial saving. Barmon et al. (2008) noted that the costs of labour, fertilizer and irrigation for conventional HYV Boro paddy production system are respectively 35%, 319% and 218% higher than for the HYV Boro rice produced within the ‘gher’ farming system.

The level of technical efficiency of ‘gher’ farming is still low at 68% implying that a substantial 47% of the potential output from the system can be recovered by eliminating inefficiency. Our results confirmed that diversification into three enterprises instead of specializing only in prawn farming has a significant impact on the level of technical efficiency. Also, the farmer’s level of education and female labour input significantly improve efficiency.

A clear policy implication that emerges from the results of this study is that diversification into enterprises currently practiced in the ‘gher’ farming system is a step in the right direction and should be a desired strategy to be replicated elsewhere, particularly the carp-rice combination. Creation of a hired labour market for female labour is also essential so that more women can be involved in the production process of this highly rewarding farming system and contribute positively towards improving productivity and efficiency. Another key policy implication is investment in education targeted at farmers which will significantly improve technical efficiency. Hopefully, the effective implementation of these measures will synergistically improve competitiveness of Bangladeshi freshwater prawn industry in the world market and raise welfare of the farming population as well.

References

Adesina, A. A., Djato, K.K. 1997. Relative efficiency of women as farm managers: profit function analysis in Cote d'Ivoire. *Agricultural Economics*, **16**: 47-53.

Ahmed, N., E.H. Allison, E.H., Muir, J.F.. 2010. Rice-fields to prawn farms: A blue revolution in southwest Bangladesh? *Aquaculture International*, (forthcoming)

Ahmed, N., Lecouffe, C., Allison, E.H., Muir, J.F. 2009. The sustainable livelihoods approach to the development of freshwater prawn marketing systems in southwest Bangladesh. *Aquaculture Economics and Management*, **13**: 246-269.

Ahmed, N., Allison, E.H., Muir, J.F. 2008c. Using the sustainable livelihoods framework to identify constraints and opportunities to the development of freshwater prawn farming in southwest Bangladesh. *World Aquaculture Society*, **39**: 598-611.

Ahmed, N., Brown, J.H., J.F. Muir, J.F.. 2008b. Freshwater prawn farming in *gher* systems in southwest Bangladesh. *Aquaculture Economics and Management*, **12**: 207-223.

Ahmed, N., Demaine, H., Muir, J.F. 2008a. Freshwater prawn farming in Bangladesh: History, present status and future prospects. *Aquaculture Research*, **39**: 806-819.

Ali, F., Parikh, A., Shah, M.K. 1994. Measurement of profit efficiency using behavioural and stochastic frontier approaches. *Applied Economics*, **26**: 181-188.

Asadullah, M.N., Rahman, S. 2009. Farm productivity and efficiency in rural Bangladesh: the role of education revisited. *Applied Economics*. **41**: 17-33.

Barmon, B.K. Kondo, T, Osanami, F. 2008. Water productivity of HYV variety of paddy production: rice-prawn and year-round paddy farming systems in Bangladesh. *Asia-Pacific Journal of Rural Development*, **18**: 99-118.

Battese, G.E., Corra, G.S., 1977. Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*, **21**: 161-179.

BB, 2007. Economic Trends (monthly publications) 2007. Bangladesh Bank, Dhaka.

Bozoglu, M., Ceyhan, B. 2007. Measuring the technical efficiency and exploring the inefficiency determinants of vegetable farms in Samsun province, Turkey. *Agricultural Systems,* **94**: 649-656.

Bravo-Ureta, B.E., Solis, D., Lopez, V.H.M., Maripani, J.F., Thiam, A., Rivas, T. 2007. Technical efficiency in farming: a meta regression analysis. *Journal of Productivity Analysis*, **27**: 57-72.

Coelli, T.J., Fleming, E., 2004. Diversification economies and specialization efficiencies in a mixed food and coffee smallholder farming system in Papua New Guinea. *Agricultural Economics*, **31**: 229-239.

Coelli, T.J., Rahman, S., Thirtle, C., 2002. Technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation: a non-parametric approach. *Journal of Agricultural Economics*, **53**: 607-626.

Coelli, T.J., Perelman, S., 1999. A comparison of parametric and non-parametric distance functions: with application to European railways. *European Journal of Operational Research*, **117**: 326-339.

Dey, M.M., Paraquas, F.J., Srichantuk, N., Xinhua, Y., Bhatta, R., Dung, L.T.C. 2005. Technical efficiency of freshwater pond polyculture production in selected Asian countries: estimation and implication. *Aquaculture Economics and Management*, **9**: 39-63.

DoF, (2009). Fishery Statistical Yearbooks of Bangladesh. Department of Fisheries, Dhaka.

DoF, (various issues). Fishery Statistical Yearbooks of Bangladesh. Department of Fisheries, Dhaka.

FAO. 1985. *Women in developing country agriculture*. Food and Agricultural Organization of the United nations, Rome.

Haji, J. 2007. Production efficiency of smallholders' vegetable-dominated mixed farming system in Eastern Ethiopia: a non-parametric approach. *Journal of African Economies*, **16**: 1-27.

Hasnah, Fleming, E., Coelli, T. 2004. Assessing the performance of a nucleus estate and smallholder scheme for oil palm production in West Sumatra: a stochastic frontier analysis. *Agricultural Systems*, **79**: 17-30.

Hossain, M., Quasem, M.A., Akash, M.M., Jabber, M.A., 1990. Differential impact of modern rice technology: the Bangladesh case. Bangladesh Institute of Development Studies, Dhaka.

Iinuma, M., Sharma, K.R., Leung, P.S. 1999. Technical efficiency of carp pond culture in peninsula Malaysia: an application of stochastic production frontier and technical inefficiency model. *Aquaculture,* **175**: 199-213.

Islam, M.S., 2008. From pond to plate: Towards a twin-driven commodity chain in Bangladesh shrimp aquaculture. *Food Policy,* **33**: 209-223.

Islam, M.S. A. Milstein, M.A. Wahab, A.H.M. Kamal and S. Dewan. 2005. Production and economic return of shrimp aquaculture in coastal ponds of different sizes and with different management regimes. *Aquaculture International*, **13**: 489-500.

Ito, S., 2004. Globalisation and agrarian change: a case of freshwater prawn farming in Bangladesh. *Journal of International Development*, **16**: 1003-1013.

Ito, S., 2002. From rice to prawn: Economic transformation and agrarian structure in rural Bangladesh. *The Journal of Peasant Studies*, **29**: 47-70.

Khondaker, H.R., 2009. Prawn hatchery development in Bangladesh: problems and potentials. In: M.A. Wahab and M.A.R. Hossain (eds.), Abstracts – National workshop on Freshwater Prawn Farming in Bangladesh: Technologies for Sustainable Production and Quality Control, 9 July 2009, Dhaka, Bangladesh, p. 11.

Kodde, D., Palm, F. 1986. Wald criteria for jointly testing equality and inequality restrictions, *Econometrica*, **54**: 1243-1248.

Kumbhakar, S.S., Orea, L. Rodriguez-Alvarez, A. Tsonias, E. G. 2007. Do we estimate an input or an output distance function? An application of the mixed approach to European railways. *Journal of Productivity Analysis*, **27**: 87–100.

Llewelyn, R.V., Williams, J.R., 1996. Nonparametric analysis of technical, pure technical, and scale efficiencies for food crop production in East java, Indonesia. *Agricultural Economics*, **15**: 113-126.

Martinez-Cordero, F.J., Leung, P.S. 2004. Sustainable aquaculture and producer performance: measurement of environmentally adjusted productivity and efficiency of a sample of shrimp farms in Mexico. *Aquaculture*, **241**: 249-268.

Rahman, S. 2010. Women's labour contribution to productivity and efficiency: empirical evidence from Bangladesh. *Journal of Agricultural Economics*, **61**: 318-342.

Rahman, S. 2009. Whether crop diversification is a desired strategy for agricultural growth in Bangladesh. *Food Policy*, **34**: 340-349.

Rahman, S. 2003. Profit efficiency among Bangladeshi rice farmers. *Food Policy*, **28**: 487-503.

Rahman, S. 2000. Women's employment in Bangladesh agriculture: composition, determinants and scope. *Journal of Rural Studies*, **16:** 497-507.

Rashid, M.H.A., Chen, J-R. 2002. Technical efficiency of shrimp farmers in Bangladesh: a stochastic frontier production function analysis. *Bangladesh Journal of Agricultural Economics*, **25**: 15-31.

Shang, Y.C., Leung, P.S., Ling, B-H. 1998. Comparative economics of shrimp farming in Asia. *Aquaculture*, **164**: 183-200.

Sharif, N.R. Dar, A. 1996. An empirical study of the patterns and sources of technical inefficiency in traditional and HYV rice cultivation in Bangladesh. *Journal of Development Studies*, **32**: 612-629.

STATA Corp, 2003. *Stata Statistical Software: Release 8.0.* Stata Corporation. College Station, Texas.

Toufique, K.A. 2001. *Structural constraint to agricultural growth: an explanation of the farm size productivity relationship in Bangladesh*. Working Paper. Bangladesh Institute of Development Studies, Dhaka.

Wadud, M.A., White, B. 2000. Farm household efficiency in Bangladesh: a comparison of stochastic frontier and DEA methods. *Applied Economics*, **32**: 1665-1673.

Wang, J., Cramer, G.L., Wailes, E.J. 1996. Production efficiency of Chinese agriculture: evidence from Rural Household Survey data. *Agricultural Economics*, **15**: 17–28.

Table 1. Expansion of shrimp/prawn area and production in Bangladesh (1986 – 2007)

Year	Khulna division			Chittagong division			Bangladesh		
	Area (ha)	Shrimp production (t)	Fish production (t)	Area (ha)	Shrimp production (t)	Fish production (t)	Area (ha)	Shrimp production (t)	Fish production (t)
1986	62,120	12,016	4,432	24,775	2,597	846	87,300	14,658	5,293
1987	62,120	11,361	5,977	24,755	3,354	1,279	87,300	14,773	7,277
1988	68,363	13,793	6,064	24,755	4,244	1,250	94,010	17,889	7,359
1989	79,728	15,049	6,938	27,453	2,983	1,905	108,280	18,235	8,937
1990	79,728	15,193	6,905	27,453	3,226	1,882	108,280	18,624	8,881
1991	79,728	15,951	7,286	27,453	3,323	1,558	108,280	19,489	8,942
1992	79,728	16,685	8,210	27,453	3,425	1,492	108,280	20,335	9,812
1993	79,728	19,198	8,571	27,453	4,073	1,558	108,280	23,530	10,243
1994	79,728	--	--	27,453	--	--	108,280	--	--
1995	104,625	26,750	11,619	29,792	6,651	1,485	137,996	34,030	13,301
1996	104,625	35,830	18,200	29,792	9,734	3,634	137,996	46,233	22,125
1997	104,625	40,443	22,084	29,792	11,127	4,354	137,996	52,272	26,748
1998	104,625	--	--	29,792	--	--	137,996	--	--
1999	107,962	--	--	29,792	--	--	141,353	--	--
2000	107,962	--	--	29,792	--	--	141,353	--	--
2001	107,962	--	--	29,792	--	--	141,353	--	--
2002	107,962	50,864	25,327	29,792	13,993	6,296	141,353	65,579	32,026
2003	107,962	51,289	27,052	29,792	14,586	6,542	141,353	66,703	34,101
2004	163,849	59,616	29,811	29,792	13,322	8,319	203,071	75,167	39,494
2005	171,505	65,559	27,946	34,704	14,648	8,611	217,877	82,661	38,049
2006	171,505	67,487	31,152	34,704	15,126	9,598	217,877	85,510	42,419
2007	171,505	68,222	31,307	34,704	15,695	9,362	217,877	86,840	42,320
% increase (1986 – 2007)	276.09	567.76	706.39	140.08	604.35	1106.62	249.57	592.44	799.55
Productivity (kg/ha) in 1986		193.43	71.35		104.82	34.15		167.90	60.63

Productivity (kg/ha) in 2007	397.78	182.54		452.25	269.77		398.57	194.24

Note: These estimates are based on catch assessment surveys conducted by Director of Fisheries at regular intervals.

Source: Fishery Statistical Yearbook of Bangladesh (various issues) published by Director of Fisheries.

Table 2. Factor shares in the ‘gher’ farming system

Factors	**Prawn + carp**		**HYV Boro rice**	
	Tk/ha	**Share of gross value**	**Tk/ha**	**Share of gross value**
Purchased inputs	122,450	23.13	7,873	12.25
Prawn	120,168	22.68	--	--
Carp	2,282	0.45	--	--
Labour	85,050	20.18	10,917	16.99
Family supplied	46,999	13.07	4,682	7.29
Hired	38,501	7.11	6,235	9.70
Male labour (Family + Hired)	77,452	18.20	9,013	14.02
Female labour (Family + Hired)	7,598	1.98	1,904	2.97
Gross value of output	544,295	100.00	61,631	100.00
Prawn (or paddy)	518,519	94.70	58,911	95.81
Carp (or straw)	25,776	5.30	2,720	4.19
Profits	336,795	56.69	42,840	69.22

Note: Purchased inputs for prawn include costs of prawn fingerlings, feed (eggs, vermicelli, fish meal, snails, oil cakes, broken rice, wheat bran, puffed rice, pulses), and chemicals (which include copper sulphate, potash, and rotanon). Purchased inputs for carp include only carp fingerling cost. Purchased inputs for rice include costs for seedlings, land preparation, irrigation, pesticides, fertilizers (urea, potash, sulphate, and gypsum).

Profits = gross value of output – variable costs (i.e., costs of purchased inputs and labour).

Exchange rate of 1 USD = 68.80 Bangladeshi Taka in 2007 (BB, 2007).

Source: Field survey, 2007.

Table 3. Summary statistics of the variables per farm

Variable	Measure	Mean	Standard deviation
Inputs			
‘Gher’ area cultivated (X_1)	Hectare	0.83	0.65
Male labour (X_2)	Person days	429.14	226.48
Female labour (X_3)	Person days	53.01	43.98
Purchased inputs (X_4)	Taka	51,005	46,605
Outputs			
Prawn (Y_1)	Kg	604.68	547.31
Carp (Y_2)	Kg	142.72	114.83
HYV rice + straw (Y_3)	Taka	31,432.29	30,008.80
Farm-specific variables			
‘Gher’ area cultivated (Z_1)	Hectare	0.83	0.65
Education of farmer (Z_2)	Completed years of schooling	6.34	3.68
Age (Z_3)	Years	41.23	14.13
Dependency ratio (Z_4)	Number	1.84	0.39
Female labour ratio (Z_5)	Proportion	0.11	0.08
Ogive index of output concentration (Z_6)	Number	1.21	0.16
Number of observations		90	

Note: Exchange rate of 1 USD = 68.80 Taka in 2007 (BB, 2007)

Table 4. Parameter estimates of the stochastic input distance functions including inefficiency effects.

Variables	Parameters	Coefficients	t-ratio
Production Variables			
Constant	α_0	-0.8294***	-25.92
ln(Male labour/Gher)	α_2	0.1632***	4.23
ln(Female labour/Gher)	α_3	-0.0180	-1.33
ln(Purchased input/Gher)	α_4	0.01437	0.49
½ ln(Male labour/Gher)^2	α_{22}	0.0731	0.79
½ ln(Female labour/Gher)^2	α_{33}	0.0057	0.43
½ ln(Purchased inputs/Gher)^2	α_{44}	-0.3208**	-2.22
ln(Male labour/Gher) x ln(Female labour/Gher)	α_{23}	0.0267	0.61
ln(Male labour/Gher) x ln(Purchased inputs/Gher)	α_{24}	0.2508*	1.64
ln(Female labour/Gher) x ln(Purchased inputs/Gher)	α_{34}	0.1324**	2.18
ln(Prawn)	β_1	-0.0256	-0.56
ln(Carp)	β_2	-0.0840***	-6.21
ln(Rice)	β_3	-0.3485***	-7.77
½ ln(Prawn)^2	β_{11}	0.4191*	1.92
½ ln(Carp)^2	β_{22}	-0.0699**	-2.41
½ ln(Rice)^2	β_{33}	0.0889	0.49
ln(Prawn) x ln(Carp)	β_{12}	-0.0597	-0.55
ln(Prawn) x ln(Rice)	β_{13}	0.0249	0.06
ln(Carp) x ln(Rice)	β_{23}	0.1929**	2.30
Model diagnostics			
Gamma	γ	0.9999***	123.5
Sigma-squared	σ_s^2	0.0035***	6.25
Log likelihood		135.91	
$\chi^2_{(18,0.99)}$		54.56***	
Inefficiency effects function			
Constant	δ_0	-0.4998***	-4.16
Ogive index of output concentration	δ_1	0.4181***	4.70
Age of the farmer	δ_2	-0.0001	-0.20
Education of the farmer	δ_3	-0.0035*	-1.64
Dependency ratio	δ_4	-0.0196	-1.02
Share of female labour	δ_5	-0.3779**	-2.35
'Gher' area	δ_6	0.1332***	9.99

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

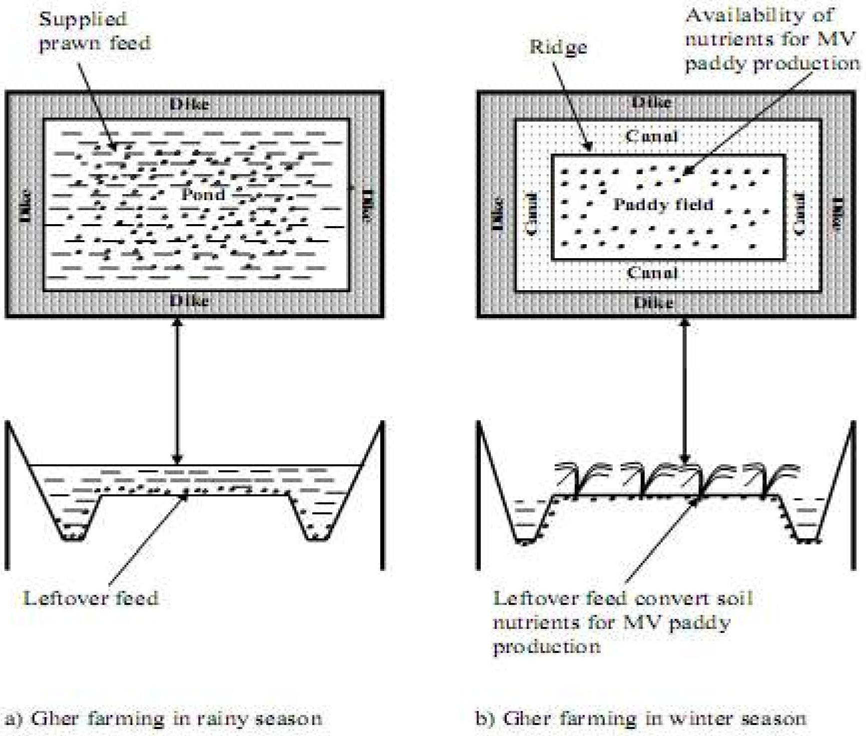
Table 5. Economies of diversification amongst enterprises

Enterprise combinations	Parameter	Coefficient	S.E.
Prawn and carp	$\hat{\omega}_{12}$	-0.0298	0.0544
Prawn and HYV rice	$\hat{\omega}_{13}$	0.0124	0.1917
Carp and HYV rice	$\hat{\omega}_{23}$	0.0965	0.0420

Note: The null-hypothesis is that there is no diversification of economies, $(\frac{\partial^2 \ln D}{\partial \ln Y_k \partial \ln Y_l} = 0,\ \forall\ k \neq l)$.

Table 6. Diversification efficiency scores

Variables	**Estimates**
Efficiency levels	
upto 50 %	21.30
51 – 60 %	15.70
61 – 70 %	12.40
71 – 80 %	12.40
81 – 90 %	22.50
90 and above	15.70
Mean efficiency level	0.68
Standard deviation	0.22
Minimum	0.08
Maximum	0.99
Number of observations	90



a) Gher farming in rainy season

b) Gher farming in winter season

Figure 1. The 'gher' farming system

Source: Adapted from Barmon et al., 2008.