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An Intra-farm Study of Production Factors and Productivity for Shrimp Farms in Bangladesh: An Index Approach

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Abstract *The production characteristics of shrimp farming in Bangladesh are reported based on a panel of farms for the period 1998 to 2002. The data allow for a profit decomposition based on the Törnqvist index, where differences in relative profits can be explained by differences in productivity, prices, and pond size. The indices indicate that pond size is the most important factor in determining profitability and that the largest farms are the most profitable. However, productivity measured as profit per hectare is only weakly positively correlated with pond size. In fact, the smallest ponds rely more on productivity in generating profit relative to the most profitable farm. These results indicate that small farms are disadvantaged not because they lack the skills to manage, but because the farms are too small. The challenge for Bangladeshi policy makers is to devise methods and procedures to allow small farmers to expand pond size.*

Key words Shrimp farms, profit decomposition, Törnqvist index.

JEL Classification Codes C43, Q22.

Introduction

Bangladesh is one of the top producers of cultured shrimp in the world and is ranked eighth in world production of farmed shrimp, with the top three producers being

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Thailand, China, and Indonesia.[1] Shrimp (mostly *Penaeus monodon*) production in Bangladesh, concentrated in the southern coastal belts of the country, has more than doubled during the last decade, from about 47,000 tonnes in 1994–95 to about 115,000 tonnes in 2003–4 (Department of Fisheries 2005). Since the mid-1980s, shrimp farming in Bangladesh has become a 100% export-oriented activity, carried out predominately by non-local entrepreneurs on leased out lands. For Bangladesh shrimp farming is second only to garment production in export earnings, generating some US$300 million annually (Export Promotion Bureau 2005). Shrimp farming also plays an important role in employment, with some 600,000 people directly involved (FAO 2007). There has been considerable effort on the part of the Department of Fisheries Bangladesh, the FAO, and the World Bank to expand and develop shrimp farming in Bangladesh.[2] In 1980 there were approximately 20,000 hectares of ponds under cultivation, and this expanded to over 200,000 hectares by 2005 (Department of Fisheries 2005).[3]

The purpose of this article is to provide an index characterization of shrimp farms in Bangladesh. There has been considerable work carried out on shrimp farming in South East Asia with emphasis on biology, environmental factors, management, and trade issues, but much less work on the economic characterization of shrimp farms (Leung and Sharma 2001; Ahmed *et al.* 2001). Though a number of studies has been carried out on shrimp farming in Bangladesh (Ahmed *et al.* 2002, Alam *et al.* 2005, Dey *et al.* 2006), no in-depth studies have been undertaken based on time series, cross sectional data. The contribution of this paper is to add to our empirical understanding of economic factors at the farm level in shrimp production.

The article is organized as follows. The next section provides some background information on shrimp farming in Bangladesh and a statistical overview of the data set used in index measurement. A description of the Törnqvist index and decomposition measure is presented, and this is followed by empirical results and discussion. Conclusions follow.

Shrimp Farming and Production Data

The technology used by shrimp farmers depends largely on the location of the farms. In the Paikgacha area, from where the samples have been drawn, farmers generally practice traditional or improved traditional shrimp culture followed by rice production during the year. In general, the intensity of culture varies inversely with farm size. However, within small farms there are two categories: traditional shrimp technologies and improved traditional shrimp technologies. In the traditional technology, farmers may just stock the ponds and use little or no other inputs. Sometimes they stock at high density. Average stocking density ranges between two and five fry per m^2. The dikes and water control measures are loose and ordinary. Farmers practicing improved traditional technology stock at a higher rate of 5–10 fry per m^2. They generally apply lime, cow dung, and urea; however, often not in adequate quantities. The dikes are relatively more stable and water control is done through concrete sluice gates. The culture period ranges between four and six

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[1] Ahmed *et al.* 2001, provide a good literature review of Bangladesh shrimp production and development through the 1990s.

[2] See Asche (2008) for an overview of world aquaculture production.

[3] Shrimp, particularly black tiger shrimp used for export, are susceptible to viral diseases such as 'White Spot Syndrome.' In addition, serious environmental problems may develop with growth in shrimp farming, see WWF online: www.panda.org/about_wwf/what_we_do/policy/agriculture_environment/commodities/shrimp/environmental_impacts/pollution/index.cfm

months from March to August, during which two to three crops are harvested. For the remainder of the year, transplanted Aman rice is generally grown. The major part of the land is owned and the rest is leased for the shrimp culture period.

The large farms generally use more traditional technologies, with stocking density ranging between two and three fry per m^2. Sometimes they apply lime, but generally not in adequate quantities. However, most of the large farms practice improved water management and control systems. They also use better conveyance and carriage facilities to transport the harvested shrimp to the local depots. The culture period ranges from four to seven months, during which two to three crops are harvested. A major part of the land of the large farmers is leased for the shrimp culture period. There is, in general, a tendency for these farmers to prolong the culture period, which impacts the production of rice by the individual lessor farmers in the subsequent season.

Land is generally rented in/out only for the shrimp culture period each year. As land rent does not vary by farm, farm-specific information on land rent was not collected. In US dollar terms, it has also remained more or less constant over the period. For the shrimp culture period only, the average land rent is about US$205 (Tk[4] 14,000) per hectare. The rental charge for the whole year, which is negotiated in some cases, is about US$280 (Tk 19,000) per hectare. Small farmers who rent out land to large/rich shrimp farmers have very poor bargaining power, and as a result land rent is low.

An interesting characteristic of shrimp farms in Bangladesh is the vast differences in farm size, from small subsistence farms of about 0.02 hectares to super-farms having more than 90 hectares of ponds. What is also interesting is that profit per hectare varies widely and in the data set used, the range is from 1,520 Tk to 171,183 Tk per hectare. For each farm size, our interest is to measure the contribution to profit of the different factors of production. The index approach used herein allows for a decomposition of profits measuring the relative importance of output and input prices, pond size utilization, and productivity. The data set used in the analysis is an unbalanced panel of shrimp farms with detailed information on revenue, factor expenditures, and pond size for 190 shrimp farms for the period 1998–2002.

The data set used is collected and collated for analysis by the WorldFish Centre and the Bureau of Socioeconomic Research and Training (BSERT) of the Bangladesh Agricultural University. The data represent production, pond area, unit price of output and inputs, and corresponding quantities. Table 1 provides a summary breakdown of the variables in the data set.

The output variables of interest are the quantity and price of shrimp. Table 1 shows a substantial range in production of farmed shrimp and that output prices per kg fluctuate between 268 Tk to 500 Tk. Table 2 shows average price and quantity for the five-year period. Price and quantity declined continuously over the period of study, with prices declining an average of 17% and quantity an average of 31%. Note the standard deviation for yearly average price, indicating substantial variations in output price of shrimp received by different fish farms. The range in prices reflects yearly variations and variations in grade (quality) and size of shrimp produced across farms. Figure 1 visually shows the wide range in prices received for shrimp by farms of different pond size, particularly for smaller pond farms.

For the other cost variables, table 1 shows price and quantity for seed, feed, labor, fertilizer, and chemicals. The price of labor is relatively similar across farms compared to prices of seed and feed. The bottom part of the table shows expenditure shares for the five input factors. Note that seed and labor combined represent, on av-

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[4] The unit of currency is the Taka (Tk) with an exchange value of 67.36 Tk to the US$, July, 2007.

Table 1
Shrimp Quantity and Price Data, Bangladesh (1998–2002)
190 Shrimp Farms

Variables	Mean	Std. Dev.	Minimum	Maximum
Quantity				
Shrimp (kg)	2,622.55	3,845.62	90	16,000
Seed (nos)	460,909.70	823,273.80	8,000	4,500,000
Feed (kg)	1,475.28	3,382.84	40	20,000
Labor (day)	1,002.70	1,090.83	30	4,050
Fertilizer (kg)	783.36	942.15	10	4,680
Chemicals[a] (kg)	992.08	2,124.25	6	11,400
Price (Tk)				
Shrimp	367.22	44.37	268.33	500
Seed	0.70	0.55	0.35	8
Feed	8.26	9.30	1.29	12
Labor	65.06	1.69	59.96	74.63
Fertilizer	8.40	0.99	4.75	10
Chemicals[a]	5.86	0.59	4.29	10.63
Pond Area (ha)	13.51	21.06	0.53	93.52
Expenditure Share				
Seed	0.585	0.176	0.192	0.907
Feed	0.034	0.025	0.004	0.107
Labor	0.312	0.166	0.043	0.698
Fertilizer	0.051	0.063	0.004	0.295
Chemicals[a]	0.016	0.0138	0.001	0.059

[a] Lime.

Table 2
Yearly Average Price (Tk) and Quantity (kg), 1998–2002
190 Shrimp Farms

Year	Price	Quantity
1998	408.2 (25.1)[a]	3,315.4 (4,484.5)
1999	387.9 (23.7)	3,062.0 (4,470.1)
2000	372.1 (37.2)	2,447.0 (3,548.1)
2001	346.8 (39.3)	2,316.4 (3,677.1)
2002	339.5 (49.0)	2,279.3 (3,387.4)

[a] Standard deviation in parentheses.

erage, almost 90% of total expenditure. The fact that feed, fertilizer, and chemicals represent only a small expenditure share probably indicates that the average shrimp farm in the data set is of the traditional production type, as described above.

Pond area shown in table 1 is measured in hectares (ha), and we observe large variation across farms, from about one-half hectare to as large as 94 hectares. In the data set, 6.0% of farms are less than 1 hectare, with 65.0% of farms between 1 and 10 hectares, and the rest (29.0%) greater than 10 hectares. Of these large ponds, 5.0% (2 farms) are larger than 50 hectares. Many of the large farms (locally known as *gher*) are on leased land from small farmers.

Judging by these summary figures and tables, shrimp farms in the data set are diverse in both size and production. Table 3 shows some average production statistics; *i.e.*, shrimp to seed ratio,[5] stocking density, and shrimp production per hectare, by three pond size groupings. The different pond sizes are an attempt to reflect differences in technology used. In terms of shrimp to seed stock ratio, farms with

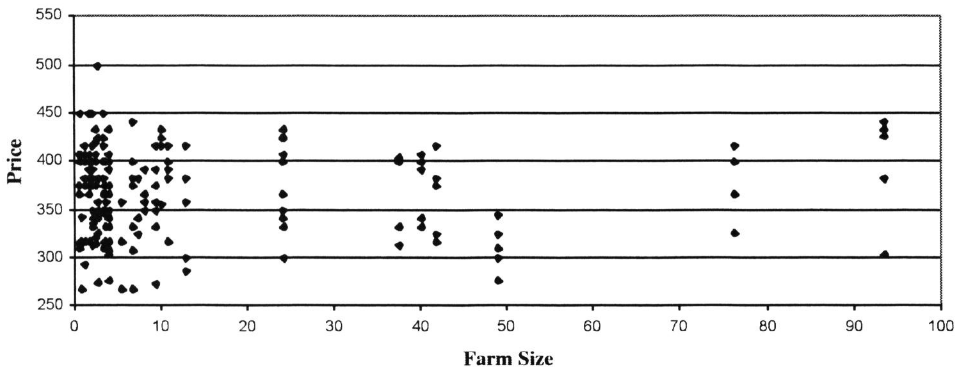

Figure 1. Price of Shrimp per kg versus Farm Size

Table 3
Average Production Statistics by Farm Size
190 Shrimp Farms

	Pond Area (ha) <20	20–60	>60
Shrimp to Seed Ratio	0.013 (0.009)[a]	0.006 (0.003)	0.007 (0.002)
Stocking Density per Hectare	21,307.5 (19 330.3)	52,611.2 (31 714.1)	22,871.6 (7 646.3)
Shrimp Production per Hectare (kg)	203.2 (118.6)	217.9 (83.8)	151.1 (49.9)
Observations	150	30	10

[a] Standard deviation in parentheses.

[5] Defined as production of shrimp (kg) per unit (nos) of seed.

ponds less than 20 hectares do considerably better than farms containing larger ponds. On the other hand, the small farms stock seed at about the same level as the largest farms, on average, which is roughly half the stocking rate of the 20- to 60-hectare farms. However, note the standard deviation for small farms is more than twice that of the largest farms. Figure 2 shows individual farm stocking rates per hectare and the wide variation in stocking rates for small farms, but also that the majority of small farms stock at less than 40,000 nos per hectare. The higher stocking rate for the 20 to 60 hectare farms results in shrimp production of about 218 kg per hectare, on average, only slightly above the smallest farms with 200 kg per hectare. However, production levels for these two farm groupings are considerably higher than for the largest farms, which show production levels of about 50–60 kg per hectare less than the other farm sizes, on average. (Note that there are only two farms, 10 observations, for the largest farm category and that these farms suffered a substantial reduction in production due to disease in the last year of the data set.)

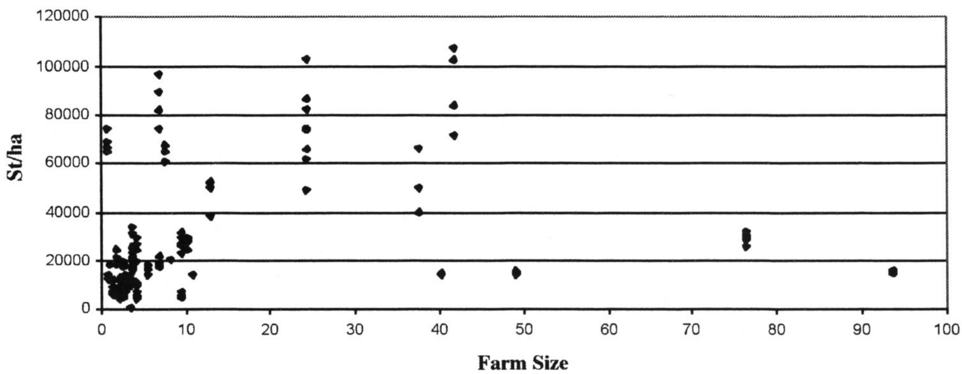

Figure 2. Stocking Rate per Hectare versus Farm Size

Table 4 reports profit per hectare of pond size for the three area groupings by year.[6] The table makes clear two important points about profits; first, for all farms, profit per hectare declined over the five-year period, and this decline was by far more damaging for larger farms than the smallest farms. Second, for each year in the data set the smallest farms showed a profit per hectare larger than other farm sizes.[7] The decline in profits reflects the serious price decline in shrimp that was mentioned above. However, the table is suggestive of farm productivity. Although the largest farms generate the largest total profit, using a productivity measure of profit per hectare, they fall short of the productivity of the smaller farms. It must also be noted that the standard deviation on profit for the smallest farms is extremely large relative to the medium and largest farms. This implies that profits are high for small farms, on average, but also some small farms are earning very low returns. (Then again some make very high returns.) We turn now to a profit decomposition procedure to measure the influence of each input factor on farm profit levels.

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[6] Profit is defined as yearly revenue minus variable costs of seed, labor, feed, fertilizer, and chemicals.

[7] These are nominal advantages, and statistically there appears to be little difference in profit levels across farm groupings, except for 2002.

Table 4
Profit per Hectare by Farm Size
190 Shrimp Farms

Year	Pond Area (ha) <20	20–60	>60
1998	54,993.8 (41,688.7)[a] [21][b]	50,763.4 (29,186.4) [6]	48,877.4 (13,243.2) [2]
1999	54,111.6 (31,233.3) [26]	53,341.5 (31,478.8) [6]	51,862.7 (1,960.0) [2]
2000	51,143.2 (38,913.5) [34]	48,472.1 (20,130.3) [6]	41,723.1 (1,680.2) [2]
2001	45,941.9 (32,912.1) [35]	35,064.9 (27,784.4) [6]	39,873.3 (17,992.2) [2]
2002	45,772.7 (30,635.1) [34]	36,680.4 (18,871.5) [6]	15,952.4 (20,410.8) [2]

[a] Standard deviation in parentheses.
[b] Number of observations.

Profit Decomposition

Insight into profit differences across farms and over time can be measured by decomposing the separate effects of prices, pond size, and productivity on the profits of individual farms. This is possible by transforming the variables using an index decomposition technique introduced by Fox *et al.* (2003). Dupont *et al.* (2005) apply the index technique to Canada's multi-species Scotia-Fundy mobile gear fishery. This section of the article is based directly on Dupont *et al.* (2005).

In general for the index procedure, all economic factors of production, both inputs and outputs, are transformed using a Törnqvist (1936) index. The Törnqvist index has desirable additive properties that make profit decomposition straightforward. The index approach does not impose economic optimizing behavior on the farms, but is an adding-up approach to the contribution of each factor input to profitability. In this way, changes in profitability can be decomposed into changes in the individual factors of production with the residual change in profitability defined as productivity. Included in the residual must be the skill of managers in operating the farm.

The Törnqvist technique relies on intra-farm comparisons to measure performance. Fox *et al.* (2003) suggest the comparison farm or 'numeraire' be defined as the farm with the largest profits in the data set. Although any farm could have been chosen, the most profitable farm is a reasonable choice for purposes of interpretation and comparison across farms and over time. The first stage in building the index is to define three identities: the ratio of profits ($\Gamma^{a,b}$), the ratio of pond size ($K^{a,b}$), and the ratio of relative prices for any farm, b, to the numeraire farm, a.

These ratios are written as:

$$\Gamma^{a,b} \equiv \frac{\pi^b}{\pi^a} \qquad K^{a,b} \equiv \frac{k^b}{k^a} \qquad P^{a,b} \equiv \frac{p^b}{p^a}, \tag{1}$$

where π represents individual farm profits, k is pond size, and p is individual factor price.

The second stage is to calculate an 'implicit' output index ($Q^{a,b}$) by dividing the profit index ($\Gamma^{a,b}$) by the relative price index ($P^{a,b}$). Using the relative output index, a productivity index ($R^{a,b}$) between the two farms is defined as the output index divided by the fixed pond input index and written as:

$$R^{a,b} = \frac{Q^{a,b}}{K^{a,b}}. \tag{2}$$

The productivity index is really the residual that is not explained by the difference in the two farms' quantity index and their relative usage of the fixed input, pond size. Rewriting equation (2) in terms of intra-farm profitability we get by definition:

$$\Gamma^{a,b} \equiv R^{a,b} \cdot P^{a,b} \cdot K^{a,b}. \tag{3}$$

Equation (3) shows that the ratio of profits between the two farms can be attributed to the relative differences in usage between productivity, price indexes, and pond size.

The final stage in building the index decomposition is to apply a Törnqvist specification to each index defined in equation (3). To set up the Törnqvist index, we need the following notation. Let q_N^i be the aggregate output vector for the i^{th} farm over N factors of production, with the output factor positively signed and input factors negatively signed. Fox *et al.* (2003) refer to this vector as a netput vector. p_N^i is the corresponding non-negative vector of prices.

The Törnqvist price index for any factor of production n, ($P_n^{a,b}$) for a given farm, b, relative to the numeraire farm, a, is defined as:

$$P_n^{a,b} \equiv \exp\left[\sum_{n=1}^{N} \frac{1}{2}(s_n^b + s_n^a)\ln\left(\frac{p_n^b}{p_n^a}\right)\right], \tag{4}$$

where s_n^b is the profit share of the n^{th} factor for farm b written as:

$$s_n^b \equiv \frac{p_n^b y_n^b}{\sum_{n=1}^{N} p_n^b y_n^b}. \tag{5}$$

s_n^a is defined in a similar fashion for farm a.

With all factor inputs defined as in equation (4), the unique properties of the Törnqvist index allow the aggregate price index between the two farms a and b to be decomposed into the product of individual price differences written as:

$$P^{a,b} = \prod_{n=1}^{N} P_n^{a,b}. \tag{6}$$

From equation (6) we can identify the relative importance of different prices upon profitability.

The Törnqvist capital or pond index is defined as:

$$K^{a,b} \equiv \exp\left[\frac{1}{2}(s_k^b + s_k^a)\ln\left(\frac{k^b}{k^a}\right)\right]. \tag{7}$$

With the profit share of pond size for farm b defined as:

$$s_k^b \equiv \frac{r^b k^b}{\sum_{n=1}^{N} p_n^b y_n^b}, \tag{8}$$

where r is the price of capital. s_k^a is defined in a similar fashion for farm a. Given that we have one fixed factor for each farm, it is reasonable to assume that profit is the return to the capital asset (pond size). Under this condition the numerator and denominator of equation (8) are equal, and the profit share of pond size for each farm is one. In this case, the Törnqvist fixed input quantity index collapses to the ratio of pond size of farm b to farm a.

Using the above equations we carry out an index profit decomposition for Bangladesh shrimp farms. For the problem at hand, the specific profit decomposition equation is represented by:

$$\Gamma^{a,b} = R^{a,b} \cdot K^{a,b} \cdot PO^{a,b} \cdot PS^{a,b} \cdot PF^{a,b} \cdot PL^{a,b} \cdot PFt^{a,b} \cdot PC^{a,b}. \tag{9}$$

The input indices are defined as: *PO* price of output, *PS* price of seed, *PF* price of feed, *PL* price of labor, *PFt* price of fertilizer, and *PC* is price of chemicals.

The individual indices on the right-hand-side of equation (9) represent the relative contribution of these variables to profits of farm b relative to the numeraire farm. Specifically, we interpret results in the following manner: If $R^{a,b}$ exceeds unity, then this implies that productivity makes a greater contribution to the profits of farm b than it does to the profits of the numeraire farm a. Similarly, if $PO^{a,b}$ exceeds unity, this implies that output price makes a larger contribution to profits for farm b than for the numeraire. On the other hand, given that higher variable costs reduce profits and that input shares in equation (4) are negative, a value for an input price index that is greater than unity implies lower factor input costs for farm b relative to the numeraire. Ultimately, this leads to higher profitability of farm b relative to the numeraire farm a.

In the next section, we will apply the index decomposition to the Bangladesh shrimp farm data.

Empirical Measurement

To apply the indices listed above, we define price and quantity variables for output and variable factor inputs. Profit is defined as revenue minus variable costs and is the return to the capital asset. The farm with the largest profits is farm 1 in 1999 and is defined as the numeraire. (This farm has the largest pond size in the data set.) The indices are calculated and individual price decompositions for each farm for each year are measured. In general, the results represent the contribution of each index category to profits relative to the numeraire. Given the large amount of individual information, the individual farm price effects are available upon request. A yearly summary of the individual price effects are reported in table 5. To read the table, consider the index values for the price of seed (1.001) and labor (0.988) in 1998. For seed, the index value indicates that the average farm paid a lower price for seed than the numeraire, whereas the average farm paid a higher price for labor relative to the numeraire. The table shows that over the five-year period there has been little change, on average, in the relative importance of input prices to profits. On average, the numeraire paid more for seed and less for labor (the two most important variable inputs in terms of expenditure) than the average farm. To provide a better description of the relative importance of input prices to profit, the average price effect for seed and labor is broken down by three farm size groupings and reported in table 6.

Table 5
Average Price Indices by Year

Year	PS	PF	PL	PFt	PC
1998	1.011	1.001	0.988	1.000	0.998
1999	1.010	0.998	0.989	1.000	0.998
2000	1.011	0.998	0.986	1.000	0.998
2001	1.039	1.001	0.984	0.999	0.998
2002	1.039	1.002	0.985	0.999	0.998

PS = Price Seed, PF = Price Feed, PL = Price Labor, PFt = Price Fertilizer, PC = Price Chemical.

Table 6
Average Price Indices by Farm Size and Year

	<20		20–60		>60	
Year	PS	PL	PS	PL	PS	PL
1998	0.986	0.987	1.100	0.993	0.999	0.993
1999	0.988	0.988	1.112	0.992	0.992	0.995
2000	0.996	0.984	1.090	0.992	1.008	0.997
2001	1.009	0.983	1.220	0.988	1.021	0.997
2002	1.006	0.983	1.220	0.991	1.039	0.996

PS = Price Seed, PL = Price Labor.

The average farm of less than 20 hectares paid more for labor than the numeraire, and this disadvantage increased over the five-year period. What this means is that the relative importance of the price of labor in determining profits decreased relative to the numeraire. For seed, the average small farm's position improved relative to the numeraire over the period. This means that the price of seed to profit determination is more important for small farms relative to the numeraire. For the average farm in the 20 to 60 hectare range the situation is clear: the numeraire paid more for seed and less for labor, indicating the relative importance of the price of seed to profit for this farm grouping compared to the numeraire. Interestingly, the price effect for seed increases the advantage of these farms compared to the numeraire. For the average large farm over 60 hectares, the numeraire again paid less for labor and more for seed. In sum, tables 5 and 6 suggest no significant input price variation over the period, although relative to the numeraire, the price of labor increased over the period and the price of seed declined.

The remaining aggregate indices (profit, productivity, capital, and output price) for profit decomposition are calculated, and the individual farm results are available upon request. Table 7 summarizes the average effects over the five-year period. The profit index is reported in the second column and shows that the average farm had profits substantially less than the numeraire. Given the vast differences in farm size, this is to be expected. However, what is interesting is that the profit index fell in each year. In other words, the average farm is becoming relatively worse off compared to the numeraire. This can be explained by the decline over time in output price reported in column 5 of the table. The average price fell continually over the five-year period. This is likely the outcome of increased competition in the world shrimp market.

Table 7
Average Aggregate Indices by Year

Year	Γ	R	K	PO
1998	0.178	1.098	0.177	0.917
1999	0.161	1.185	0.156	0.851
2000	0.123	1.171	0.135	0.796
2001	0.099	1.121	0.132	0.696
2002	0.081	1.129	0.133	0.657

Γ = Profit, R = Productivity, K = Pond Area, PO = Output Price Index.

The capital index reported in column 4 shows that the real advantage of the numeraire is its large size and that this advantage improved over the period (or more accurately, for other farms the contribution of capital decreased over the period).

Finally, we report the productivity index listed in column 3. The results show that the contribution of productivity to profit was higher for the average farm relative to the numeraire over the five-year period. The productivity index was highest in 1999, declining somewhat over the remaining years in the data set. Keep in mind that the productivity index is measured as the residual not explained by variable or fixed factor inputs. As such, the index will measure not only productivity but exogenous shocks and factors not specifically accounted for in the Törnqvist index. Two such factors may be important for the productivity index listed here; variations in stocking density across farm groupings and the virus outbreak that impacted the largest farms in 2002.

To address the productivity index across farms and over time in more detail, table 8 breaks down the aggregate indices by three pond groupings for each year in the data set. We observe that for the medium and largest farms, the productivity index declined over the five-year period relative to the numeraire. The serious decline in productivity for the largest farms in 2002 can be explained by the virus outbreak. However, for the medium-size farms with a higher stocking density than the numeraire, it is reasonable to conclude that productivity relative to the numeraire has declined. On the other hand, for small farms less than 20 hectares we measure a higher productivity over the five-year period relative to the numeraire. Before we

Table 8
Average Aggregate Indices by Farm Size

Hectares		1998	1999	2000	2001	2002
<20	Γ	0.059	0.053	0.051	0.042	0.039
	R	1.124	1.210	1.222	1.168	1.184
		(0.877)[a]	(1.099)	(0.979)	(1.029)	(1.024)
	K	0.049	0.045	0.045	0.044	0.044
	PO	0.922	0.847	0.772	0.705	0.685
20-60	Γ	0.382	0.386	0.338	0.246	0.260
	R	1.063	1.125	0.991	0.923	0.994
	K	0.385	0.385	0.385	0.385	0.385
	PO	0.874	0.836	0.866	0.601	0.591
>60	Γ	0.816	0.885	0.712	0.657	0.246
	R	0.944	1.034	0.830	0.899	0.594
	K	0.907	0.907	0.907	0.907	0.907
	PO	0.986	0.947	0.936	0.820	0.385

Γ = Profit, R = Productivity, K = Pond Area, PO = Output Price Index.
[a] Farms with stocking density less than 40,000 nos/ha.

conclude a productivity advantage for small farms, we must determine the importance of stocking density on this index.[8] In the productivity row of table 8, the number in parentheses for small farms shows the calculated index after dropping small farms with a stocking density greater than the numeraire.[9] Certainly the stocking density impacted the productivity index, but we still observe a productivity advantage for smaller farms relative to the numeraire in 1999, 2001, and 2002.

Given the number of small farms in shrimp production and the pond size differences between the largest and smallest ponds, the profit indices are recalculated using all shrimp farms less than 20 hectares; a total of 150 farms. Within this subgroup, farm 32 in 1998 had the largest profit and is now the numeraire. This farm has a pond area of 12.82 hectares. The results for individual price and aggregate indices are reported as yearly averages and presented in tables 9 and 10, respectively.

Table 9 shows very little variation in prices between the numeraire and the average small farm. The importance to profits of the price of labor, fertilizer, and chemicals is unchanged over the period, whereas we see some minor changes in price of seed and fertilizer. In general there is very little to differentiate the numeraire from the average small farm based on variable input prices, except the price of seed, over the five-year period.

Table 10 shows aggregate indices, and here we see some variation across farms. Profits fell over this period, but not as drastically as for the full data set. Again, output prices are the main reason for profit decline. It is interesting that output prices, although declining, did not fall as drastically as for the full dataset. It is possible that this indicates that the small farms are better at producing high-quality or optimal-size shrimp for the markets relative to larger firms. The capital index shows a relative decline in the importance of pond size on profits for the period. Finally, the productivity index shows that the average small farm is disadvantaged relative to the numeraire in this category, but average productivity improved over the period.

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[8] We thank an anonymous referee for identifying this point.
[9] Observations of small farms with a stocking density greater than 40,000 nos/ha were dropped from the index.

Table 9
Average Price Indices of Farms with less than 20 Hectares

Year	PS	PF	PL	PFt	PC
1998	0.907	0.995	0.997	1.000	1.000
1999	0.916	0.991	0.999	1.000	1.000
2000	0.916	0.991	0.999	1.000	1.000
2001	0.916	0.993	0.999	1.000	1.000
2002	0.906	0.995	0.999	1.000	1.000

PS = Price Seed, PF = Price Feed, PL = Price Labor, PFt = Price Fertilizer, PC = Price Chemical.

Table 10
Average Aggregate Indices of Farms with less than 20 Hectares

Year	Γ	R	K	PO
1998	0.148	0.387	0.357	0.977
1999	0.133	0.415	0.331	0.897
2000	0.126	0.418	0.331	0.821
2001	0.105	0.401	0.327	0.751
2002	0.097	0.410	0.318	0.730

Γ = Profit, R = Productivity, K = Pond Area, PO = Output Price Index.

Conclusions

The contribution of the index approach to intra-farm comparisons is based on a relative scale of each farm to a numeraire. In this comparative manner, the policy makers can evaluate the importance of individual factor inputs to profit levels for each farm relative to the numeraire and over time. Thus, this technique provides an index measure of change in the importance of individual factors in profit decomposition (Fox *et al.* 2003).

The index approach to Bangladesh shrimp farms has provided some interesting results and, in addition, the indices are suggestive of some underlying economic conditions. The first point is that farm size is the important factor in determining profitability and, not surprisingly, that the largest farms earn the highest profit. What is interesting is that productivity measured as profit per hectare is only weakly positively correlated with pond size. In fact, the smallest ponds in the later years rely more on productivity/management skills in generating profit relative to the numeraire.

These results indicate that small farms are disadvantaged not because they are unproductive or lack the skills to manage the farms, but that they are too small. This result is suggestive of important scale effects with respect to pond size. The challenge for Bangladeshi policy makers is to devise methods and procedures to allow small farmers to expand farm size.

References

Ahmed, S.A., D.L. Mallick, M.L. Ali, and A.A. Rahman. 2001. Policy Research for Sustainable Shrimp Farming in Asia. A Comparative Analysis of Bangladesh, India, Thailand, and Vietnam with Particular Reference to Institutional and Socio-economic Aspects. Project PORESSFA Project No. IC4-2001-10042 www.bcas.net/Publication/Documentation/PORESSFAfinal.pdf

___. 2002. Literature Review on Bangladesh Shrimp. Report for the Project: Policy Research for Sustainable Shrimp Farming in Asia (PORESSFA). European Commission INCO-DEV Project No. IC4-2001-10042, CEMARE-University of Portsmouth, UK, and BCAS, Dhaka, Bangladesh, 31 p.

Alam, N.S.M., C.K. Lin, A. Yakupitiyage, H. Demaine, and M.J. Philips. 2005. Compliance of Bangladesh Shrimp Culture with FAO Code of Conduct for Responsible Fisheries: A Development Challenge. *Ocean and Coastal Management* 48(2):177–88.

Asche, F. 2008. Farming the Sea. *Marine Resource Economics* 23(4):527–47

Department of Fisheries. 2005. *Fishery Statistical Yearbook of Bangladesh 2004–2005*. Fisheries Resources Survey System, Department of Fisheries, Government of Bangladesh. www.fisheries.gov.bd/fish_yearbook.htm

Dey, M.M., K. Roslina, F. Paraguas, and R. Bhatta. 2006. The Economics of Shrimp Farming in Selected Asian Countries. *Shrimp Farming, Economics and Trade*, P. Leung and C. Engle, eds., pp. 241–61. Oxford: Blackwell Publishing.

Dupont, D.P., J.K. Fox, D.V. Gordon, and R.Q. Grafton. 2005. Profit and Price Effects of Multi-species Individual Transferable Quotas. *Journal of Agricultural Economics* 56(1):31–57.

Export Promotion Bureau, Ministry of Commerce, Republic of Bangladesh. 2005. Statement of Monthly Exports. www.epb.gov.bd/Statistics2005-06.html

Food and Agriculture Organization of the United Nations (FAO). 2007. National Aquaculture Sector Overview—Bangladesh. www.fao.org/fi/website/FIRetrieveAction.do?dom=countrysector&xml=naso_bangladesh.xml&lang=en

Fox, K.J., R.Q. Grafton, J.E. Kirkley, and D. Squires. 2003. Property Rights in a Fishery: Regulatory Change and Firm Performance. *Journal of Environmental Economics and Management* 46:156–77.

Leung, P.S., and K.R. Sharma. 2001. Economics and Management of Shrimp and Carp Farming in Asia: A Collection of Research Papers based on the ADB/NACA Farm Performance Survey. Network of Aquaculture Centers in Asis-Pacivic (NACA) Bangkok, Thailand. www.biotec.or.th/shrinfo/documents/EconomicsManagement.pdf

Törnqvist, L. 1936. The Bank of Finland's Consumption Price Index. *Bank of Finland Monthly Bulletin*, No. 10:1–8.