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A Multistage Budgeting Approach to the Analysis of Demand for Fish: An Application to Inland Areas of Bangladesh

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Abstract *This study was conducted to estimate the elasticities of demand for eight different fish types and four income groups in Bangladesh using year-round data collected from inland areas of the country. It uses a three-stage budgeting framework that estimates a demand function for food in the first stage, a demand function for fish (as a group) in the second stage, and a set of demand functions for fish by type in the third stage using a quadratic extension of the Almost Ideal Demand System (QUAIDS) model. The Heckman procedure was used in stage three to remove the possible bias in the parameter estimates brought about by zero consumption. The magnitude of both price and income elasticities varies across different fish types and income quartile groups, indicating the relevance of estimation specific to fish types and quartiles. Except for assorted small fish, the other seven fish types included in the study were found to have positive income elasticity for all income levels. Assorted small fish is an inferior commodity for the richest quartile of the population.*

Key words Bangladesh, fish demand elasticities, Inverse Mills Ratio, multi-stage budgeting, quadratic extension to Almost Ideal Demand System (QUAIDS).

JEL Classification Codes C3, Q21.

Introduction

The aquaculture and fisheries sector plays an important role in developing countries, providing nutrition, income, employment, and foreign exchange (Smith *et al.* 2010). As in many other Asian countries, food fish plays a major role in human nutrition in Bangladesh by supplying about 66% of total animal protein intake, which constitutes about 14% of a person's total protein intake (Bangladesh Bureau of Statistics 2007). Fisheries and aquaculture development is also considered as an important vehicle for reducing poverty and improving food security in the country (Government of Bangladesh 2004; Karim *et al.* 2006). The Government of Bangladesh is committed to developing appropriate strate-

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gies and policy support for encouraging additional investment in aquaculture and fisheries to increase their contribution to the economy.

Information on fish demand and how it is likely to change as production/supply, prices, and incomes change, is required to assess the impact that technological change, infrastructure development, and economic policies will have on food security and the distribution of fish in developing countries like Bangladesh. Knowledge of future demand for fish is important to private investors and decision makers. Information on price and income elasticities of demand for fish is required to estimate future demand and assess the welfare and distributional impacts of various technological and policy changes. This information must be specific for different types of fish and different income classes, as fish is a heterogeneous commodity (Westlund 1995; Smith, Griffiths, and Ruello 1998), and consumer preference varies widely across income classes (Dey *et al.* 2005). The notion of product heterogeneity is particularly important in Bangladesh and other Asian countries. In this region, unlike in many western and developed counties where processed and value-added fish products are more popular, consumers generally prefer whole fish or choice cuts like head, belly, roe, etc. Hence, consumers distinguish among the various fish types based on attributes such as size, scale color, flesh color, bone content, etc.

Although a large number of studies focusing on demand for fish and seafood products have been published over the last two decades or so, most of these studies focus on developed countries (Asche, Bjørndal, and Gordon 2007; Gallet 2009). Studies on elasticities of demand for fish in Asia, in general, and in Bangladesh, in particular, are few. Most of the available studies on demand for fish in Bangladesh considered fish as one of the commodity groups in their demand models and analyzed aggregate fish demand (Pitt 1983; Hossain 1988; Goletti 1992; Talukder 1993; Ahmed and Shams 1994; Shahabuddin and Zohir 1995; Razzaque, Khondoker, and Mujeri 1997). So far, only Dey (2000) and Ali (2002) estimated disaggregated demand for fish in the country. Dey (2000) was based on limited household expenditure data collected by the Bangladesh Bureau of Statistics (BBS), where total consumption information encompasses only one week. Ali (2002) used survey data collected in 1994 and analyzed demand for fish for four aggregated fish categories (low-priced, medium-priced, high-priced, and dry).

The present study improves upon the previous research efforts in that it: *i)* uses data collected on a weekly basis for all 52 weeks of the year; *ii)* has sufficient geographical coverage to be representative of the country; and *iii)* considers eight different types of fish and four quartile groups of consumers.[1] Moreover, the present study has brought some improvement in the methodology and estimation procedure over the Dey (2000) study. It is expected that this study will not only be helpful for the country concerned, but also provide useful guidance for future demand studies in the region. The analytical framework used in the study can be applied to other commodity groups.

The article is arranged in five sections. Following this section on background of the study, the next section describes the data. This is followed by a description of the analytical techniques used. The results and discussion are then presented, and the article concludes with conclusions and policy implications.

[1] The current analysis uses monthly transformed data of food and non-food expenditures collected from eight *Upazillas* (sub-districts) of four districts of Bangladesh over a one-year period (1998–99). The *Upazillas* (*Thanas*) and districts investigated were Chandina and Burichong in Comilla district, Bogra Sadar and Sariakandi in Bogra district, Bagharpara and Zhikargacha in Jessore district, and Trishal and Ishwarganj in Mymensingh district. Another contribution of this research is that the data allow analysis of tilapia as another species type. Tilapia has become an important cultured species. During the national Household Income Expenditure Survey (HIES) in 1988–89, tilapia as a food commodity was aggregated to "other fish." During the HIES 2000, it was considered as a separate commodity.

Data

Survey Design and Data Collection

The analysis in this research is based on data collected by the WorldFish Center and the Bureau of Socioeconomic Research and Training (BSERT) of the Bangladesh Agriculture University under the "Genetic improvement of carp species in Asia" project[2] during the period 1998–99 (ICLARM 2001). Specifically, these data are from a consumer survey that was undertaken to study the fish consumption pattern of different segments of the population covering four inland districts of the country. For each of these districts, two sub-districts (locally known as *Upazillas* or *Thanas*) were selected. For each of the eight sub-districts, 90 sample respondents were selected through a stratified random sampling procedure, consisting of 30 respondents or households for each of the three groups: fish producer-consumer, urban non-producer consumer, and rural non-producer consumer. Thus, the number of samples collected from each district was 180, totaling 720 in four districts. A year-round survey was conducted, starting in July 1998 and ending in August 1999, generating weekly time-series, cross-section data.[3] Due to very high incidence of zero consumption of some specific fish species during a week *(i.e.*, infrequency of purchases), the data were then converted to a monthly series for analysis.

There were about 40 different types of fish species consumed by the household samples, all of which could not be analyzed independently for the purpose of demand estimation. Some aggregations of species, therefore, had to be made in order to manage the analysis properly. In total, eight groups/types comprising single and aggregated species of fish were incorporated in the analysis for demand estimations. These eight species types and their composition are summarized in table 1. Hilsa (*Tenualosa ilisha*) formed a separate type, as it occupies a very significant position in total fish production of the country. Tilapia also formed a separate group, as it has become an important species in the country (see footnote 1). Shrimp and prawns of different species were grouped together, but the presence of the large freshwater prawn (*Macrobrachium rosenbergii*) in the fish consumption basket was very minimal, as its price is very high, often beyond the purchasing capacity of the majority of the people.

Though the data set used in this study is about ten years old, the results and estimated demand elasticities of this study would not be very different from those based on a very recent data set. Fish is not only important for human nutrition in Bangladesh, it is also part of Bangladeshi culture. There is an old Bengali proverb: *masse-bhatee Bangali* (rice and fish makes a Bengali). Fish demand in Bangladesh remains unmet, and fish consumption is still below the recommended dietary allowance (Dey, Bose, and Alam 2008). Most of the fish consumed in Bangladesh is from domestic production. After a dramatic increase in aquaculture production during 1980s and 1990s (Dey, Bose, and Alam 2008), the pattern of fish production in Bangladesh and the shares of different species in national production have remained relatively unchanged during the last decade (Department of Fisheries (DOF) 2010). Also, consumers' preferences for different broad categories/types of fish (*e.g.*, the eight types used in this study) have not changed over the last decade or so.

[2] The first two authors of this article led implementation of the project in Bangladesh and collection of data used herein.

[3] Eight enumerators were employed to collect the data using a pre-tested questionnaire. The enumerators visited individual sample respondents every weekend and completed their food and non-food consumption information for the past week. Thus, a total of 52 visits were made to each respondent. A research officer scrutinized the collected data during the data collection process. Inconsistent and incomplete questionnaires were sent back to the field for validation/correction.

Table 1
Species Groups, Composition, and Weighted Average Price

Species Group	Species Composition English/Local Name (scientific name)	Weighted Average Price (Taka/kg)*
Indian major carp	Rohu (*Labeo rohita*) Mrigal (*Cirrhinus cirrhosus*) Catla (*Catla catla*) Kalibaus (*Labeo calabasu*)	54.38
Exotic carp	Silver carp (*Hypophthalmichthys molitrix*) Grass carp (*Ctenopharyngodon idella*) Mirror carp (*Cyprinus carpio var. specularis*) Common carp (*Cyprinus carpio*) Sarpunti (*Puntius sarana*)	40.24
Hilsa	Hilsa (*Tenualosa ilisha*)	64.74
Assorted small fish	Punti (*Puntius spp*.) Tengra (*Mystus spp*.) Mola (*Amblypharyngodon mola*) Batashi (*Pseudeutropius atherinoides*) Chanda (*Chanda spp.*) Lati/taki (*Channa panctatus*) Gonchoi (*Mastacembelus pancalus*) Khalisa (*Colisa spp*.)	31.28
High-valued fish	Pangus (*Pangasius pangasius*) Boal (*Wallago attu*) Chital (*Notopterus chitala*) Aior (*Mystus aor* or *Aorichthys aor*)	83.60
Tilapia	Tilapia (*Oreochromis niloticus*)	43.18
Shrimp and prawn	Prawns and shrimp of different species	80.56
Live fish	Shingi (*Hetropneustes fossilis*) Magur (*Clarias batrachus*) Koi (*Anabus testudineus*) Sol (*Channa spp*.)	65.41

* 1999 Exchange Rate: 1 US$ = 49 Taka (Bangladeshi currency).

Data Overview: Fish Consumption Patterns in Bangladesh

The present study estimated per capita fish consumption to be 22.2 kg/year, which is higher than the national average (table 2). In Bangladesh, as in many developing countries, official national statistics on per capita fish consumption are commonly based on the total availability of commercial fish in the country and do not include the consumption of many small and non-commercial fish species obtained from artisanal and subsistence fisheries. It is generally assumed that actual per capita fish consumption is higher than the national average reported in official databases (Ahmed, Tana, and Thouk 1996; FAO 1999, 2002; Welcome 2001; Dey *et al*. 2005). The national average fish consumption in Bangladesh, as reported by FAO and other official databases (*e.g*., data published by BBS and DOF), also fails to include the consumption of fish unofficially imported from neighbouring countries. The estimated per capita consumption reported in this article (22.2 kg/capita/year) is probably representative of the actual situation in the country.[4]

Table 2

Consumption Pattern of Fish in Different Income and Consumer Groups

	Fish Consumption and Expenditure								
Group	Indian Carp	Exotic Carp	Hilsa	Assorted Small Fish	Live Fish	Tilapia	Shrimp and Prawn	High-Valued Fish	All Species
Monthly consumption by income groups (kg)									
Quartile 1	0.23	0.25	0.09	0.36	0.06	0.05	0.05	0.02	1.10
Quartile II	0.34	0.33	0.14	0.51	0.12	0.06	0.07	0.05	1.61
Quartile III	0.43	0.38	0.16	0.56	0.15	0.08	0.06	0.07	1.89
Quartile IV	0.63	0.57	0.25	0.71	0.24	0.18	0.10	0.11	2.80
All groups	0.40	0.38	0.16	0.54	0.14	0.09	0.08	0.06	1.85
Monthly consumption by consumer groups (kg)									
Producer consumer	0.42	0.39	0.16	0.57	0.14	0.09	0.07	0.05	1.92
Rural consumer	0.35	0.35	0.15	0.49	0.13	0.09	0.08	0.05	1.69
Urban consumer	0.44	0.40	0.16	0.55	0.14	0.10	0.08	0.07	1.96
All groups	0.40	0.38	0.16	0.54	0.14	0.09	0.08	0.06	1.85
Monthly fish expenditure share (percent of income spent on fish consumption)									
Quartile 1	0.22	0.20	0.09	0.27	0.03	0.05	0.06	0.09	1.00
Quartile II	0.23	0.19	0.10	0.23	0.05	0.04	0.07	0.10	1.00
Quartile III	0.25	0.19	0.09	0.21	0.05	0.05	0.05	0.10	1.00
Quartile IV	0.24	0.19	0.10	0.20	0.05	0.07	0.06	0.10	1.00
All groups	0.24	0.19	0.10	0.23	0.04	0.05	0.06	0.09	1.00
Per capita per annum (kg)	4.80 (22.0)	4.56 (21.0)	1.92 (9.0)	6.48 (29.0)	1.68 (7.5)	1.08 (4.6)	0.96 (4.0)	0.72 (3.5)	22.20 (100.0)

Note: Figures in parentheses indicate percent share of total fish consumption.

Fish consumption in Bangladesh varies across different income groups (table 2). For example, the monthly consumption of the bottom income quartile is only 1.10 kg/capita, which is less than half that of the highest quartile group. Fish consumption also varies

[4] Other micro-level surveys of fish consumption recently conducted in Bangladesh report much higher per capita fish consumption, at about 31 kg/capita/year (Thompson, Sultana, and Firoz Khan 2004; Sultana and Thompson 2000).

across different types of consumers. Urban consumers appear to have the highest fish consumption (1.96 kg/capita/month), followed by producer consumers (1.92 kg/capita/month) and rural consumers (1.69 kg/capita/month). As for specific species, the highest consumption is of assorted small fish, accounting for 29% of the total fish consumption. This is followed by Indian carp (22%) and exotic carp (21%). The shares of other species are: 9% for hilsa, 7.6% for live fish, 4.7% for tilapia, 4% for shrimp and prawn, and 3.5% for high-valued species.

Fish expenditure by type also varies across income groups. While the high-income groups spend more on Indian carp (24 to 25% of their total fish expenditure), assorted small fish constitutes the highest fish spending among the low-income group (27%). In general, Indian carp and assorted small species constitute 24 and 23% of the total fish expenditure, respectively. This is closely followed by exotic carp, which accounts for 19% of the total fish expenditure. These three species together comprise two-thirds of total fish expenditures. This appears to be quite consistent with reality. The shares of other species ranged between 4 and 10%.

There is a seasonality pattern of per capita fish consumption, which is in inverse relation to the weighted average price of fish. This relationship and patterns could be attributable to the seasonality of fish supply. During the first quarter of the year (January–March), open waters like rivers, canals, and beels dry up, and the fish catch from open water increases, as does fish availability in markets. During the third quarter (July–September), cultured fish attain marketable size and the market supply increases.

Except for shrimp and prawn, all species similarly follow the seasonal pattern (figure 1). The assorted small fish, which are mostly from freshwater capture fisheries, seem to be the major driving factor for this seasonality pattern, followed by cultured Indian carp and exotic carp.

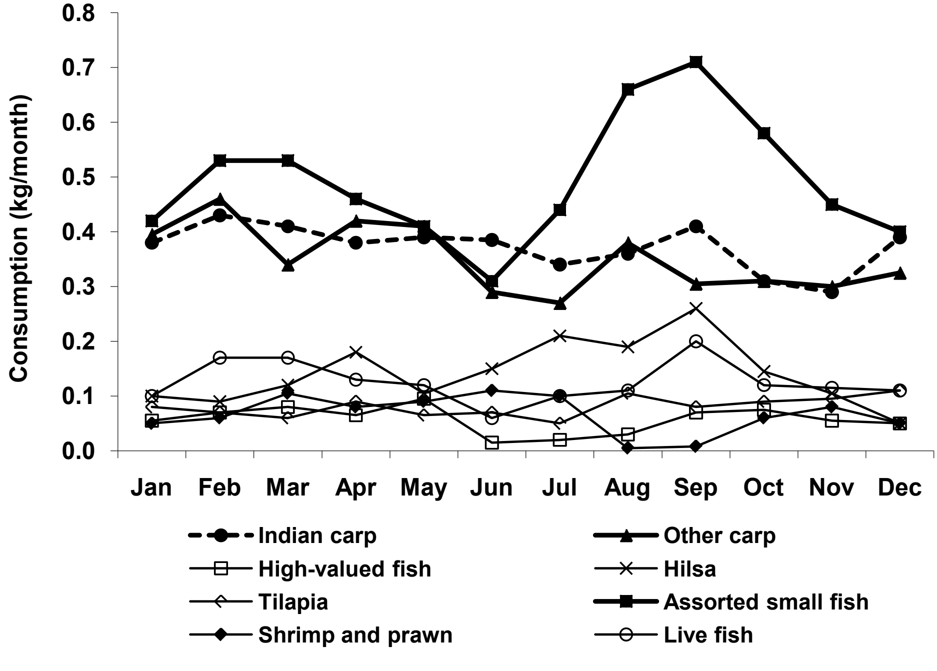


Figure 1. Seasonality of Fish Consumption by Species Group

Methodology

Analytical Framework

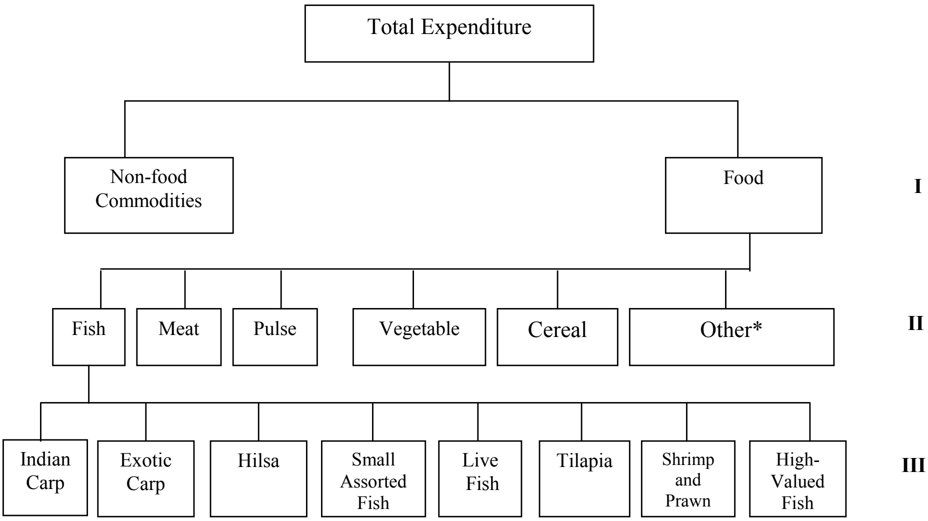
We used a multistage budgeting framework which extends the idea of an exhaustive expenditure system to different levels or stages. This framework addresses a common problem in empirical estimation of system demand models requiring a sizeable number of equations, given the wide variety of consumption goods jointly purchased by households (Blundell, Pashardes, and Weber 1993; Fan, Wailes, and Cramer 1995). Specifically, a full demand system containing all consumer goods warrants a huge number of own- and cross-price parameters that are impractical to estimate under the constraint of limited data. One solution is to estimate the model in stages, whereby expenditures on goods belonging to broad food categories are incorporated in the model by estimating them sequentially.

We applied a three-stage budgeting approach that estimated food and fish expenditure functions in the first and second stages, respectively. In the third stage, a system of demand equations for fish by species type was estimated using a quadratic extension of the AIDS (QUAIDS) model, which has recently proved popular (Blundell, Pashardes, and Weber 1993; Garcia, Dey, and Navarez 2005). The quadratic nature of the QUAIDS model captures the non-linearity in consumption behavior of households for goods. At the same time, it relaxes the restriction imposed by linear demand functions regarding the allocation of marginal expenditures among commodities, assuming them to be the same in rich and poor households (Beach and Holt 2001). Such assumptions limit the classification of goods into either necessities or luxuries and deny the possibility that some goods may be luxuries at a low-income level and necessities at a higher income level (Garcia, Dey, and Navarez 2005).

A schematic diagram depicting the three stage-budgeting framework for eight species groups in Bangladesh is displayed in figure 2. In the first stage, the households are assumed to make decisions on how much of the predetermined income is to be allocated for food expenditure. Food expenditure is considered to involve a function of income, prices of food and non-food items, household characteristics (such as family size), and a set of dummy variables [time (months), districts, and urban/rural divide]. In the second stage, each household allocates a portion of the food expenditure for fish consumption, the amount of which is assumed to be dependent on prices of different food items (e.g., fish, cereal, meat, chicken, eggs, milk, vegetables, spices, pulses, oil) and other dummy variables as specified in the first stage. Finally, the expenditures for different types of fish are estimated in the third stage, using the prices of different types of fish, per capita fish expenditures, and dummy variables as mentioned earlier.

It is likely to have zero consumption of specific fish categories, which may be due to any of the three broad factors: *i)* variations in preference across samples (households may simply not consume some species); *ii)* infrequent purchasing; and *iii)* misreporting (Keen 1986). In addition, due to the seasonal variability, the supply of a particular fish may not be available in the market; therefore, certain species may not be consumed. Various models for dealing with zero observation problems have been proposed by Deaton and Irish (1984); Keen (1986); Blundell and Meghir (1987); Heien and Wessells (1990).

We used the approach applied by Heien and Wessells (1990) to deal with zero observations in the sample, as this is especially related to the AIDS model function. Our particular application involves a special case of the censored simultaneous equation model in which the dependent variables are censored by a sub-set of unobservable latent variables. The dependent variables, which are budget shares of the species of fish, are either zero or some positive amount for each household. Those shares of zero values are censored by an unobservable latent variable that induces the decision not to purchase that particular item during the survey period. The decision to buy or not to buy can be indicated by a binary indicator variable, which is a function of the latent variables and is estimated using the Probit model (Lee 1978). The assumptions underlying this model (and its proof) are that: *i)* the individual observations are independently and identically distributed and *ii)* the error terms are approximately normal with zero mean and a finite variance-covariance matrix that is constant over all observations.



* Other food items are included in the empirical analysis.

Figure 2. Three-stage Budgeting Framework for Estimation of Fish Demand

Empirical Model: Overview

Existing literature indicates that previous studies have different model specifications (Asche, Bjørndal, and Gordon 2007; Gallet 2009). It is important to note that analysis of fish demand is an empirical exercise, and each study must be based on a model that is appropriate for the specific market in a particular time period. Given the fish market and consumption behavior in Bangladesh, we have developed the empirical model with due consideration of three main issues: *i)* weakly separable utility functions; *ii)* non-linearity in consumption behavior (*i.e.*, quadratic income or expenditure terms); and *iii)* selection bias due to zero consumption. The empirical model used in this study for analyzing fish consumption behavior of a representative household is described in detail in the following three subsections.[5] For notational simplicity, we have omitted the subscript for household.

Empirical Model: Stage One

Following Blundell, Pashardes, and Weber (1993) and Dey (2000), the functional form of food expenditure has been specified to be of the quadratic type. The econometric specification of the model is as follows (for simplicity, we omit the subscripts for unit and time):

[5] A different empirical model might change the results. We believe, as discussed in previous sections, that this model is most appropriate for analyzing fish consumption behavior in Bangladesh.

$$\ln M = \alpha_0 + \alpha_1 \ln P_f^* + \alpha_2 \ln I + \alpha_3 \left(\ln I\right)^2 + \ldots$$
$$+ \alpha_4 NF + \alpha_5 FS + \sum_{i-1}^{3} \delta_i R_i + \sum_{i-1}^{11} \varphi_i T_i + \lambda C + \varepsilon, \quad (1)$$

where ln denotes natural logarithm; M is monthly per capita food expenditure (in Taka); I is monthly per capita income (in Taka); NF is monthly per capita non-food expenditure (in Taka); FS is family size (number); R_i are district dummies, R_1 pertains to Jessore (*i.e.*, $R_1 = 1$ if district = Jessore, and = 0 if otherwise), R_2 pertains to Bogra, and R_3 pertains to Mymensingh (Comilla is the base dummy); the T_i are the 11 monthly dummy variables (December is the base dummy); C denotes urbanity dummy variable, which takes a value of 1 if it is urban, and 0 if otherwise; and α, δ, φ, and λ are the corresponding parameters to be estimated. The $\ln P_f^*$ is the Stone Price Index (SPI) (after Stone 1953) of food computed as:

$$\ln P_f^* = \sum_{j-1}^{m} w_j \ln Pfd_j, \quad (2)$$

where w_j and Pfd_j are the expenditure shares and prices of commodity j, respectively.

The income variable (I) was included in the model both in linear and squared forms. The quadratic income term $(\ln I)^2$ aims to capture the possible non-linearity in food consumption behavior of households with respect to income. Due to data constraints, per capita expenditure for non-food commodities was used as a proxy variable for the price index of non-food commodities (*PNF*). This proxy variable takes into account the 'income effect' of the changes in *PNF*. Given that food expenditure is more important than non-food expenditure in Bangladesh and that there has been no dramatic movement of non-food prices in the county, we further assume that the 'substitution effect' between food and non-food commodities is negligible.[6] The food expenditure equation (1) has been estimated according to the Ordinary Least Square (OLS) method, imposing homogeneity of degree zero in prices and income restriction as:

$$\frac{\partial \ln M}{\partial \ln P_f^*} + \frac{\partial \ln M}{\partial \ln I} = \alpha_1 + \alpha_2 + 2\alpha_3 \ln I + \alpha_4 = 0. \quad (3)$$

Empirical Model: Stage Two

In the second stage, households are assumed to make decisions on aggregate fish expenditure conditional on prices of fish, other food and non-food items, per capita food expenditure, and the set of dummy variables as defined earlier. The model for the fish (aggregated) expenditure function is expressed as:

[6] This assumption does not allow us to analyze the distributional impact of the changes in non-food prices, which is not the focus of this article.

$$\ln F = \theta_0 + \sum_{i-1}^{k} \beta_i \ln Pfd_i + \theta_1 \ln M^* + \theta_2 \left(\ln M^*\right)^2 + \ldots$$
$$+ \sum_{i-1}^{3} \delta_i R_i + \sum_{i-1}^{11} \varphi_i T_i + \lambda C + \varepsilon, \quad (4)$$

where F is monthly per capita fish expenditure (in Taka); Pfd_i is the price of commodity i (*i.e.*, fish, rice, meat, chicken, eggs, vegetables, spices, pulses, and oils); and M^* is the predicted monthly per capita food expenditure derived from equation (1). Other variables are as defined in equation (1).

Equation (4) has also been estimated by the OLS method. The homogeneity restriction was imposed as:

$$\sum_{i-1}^{k} \frac{\partial \ln F}{\partial \ln Pfd_i} + \frac{\partial \ln F}{\partial \ln M^*} = \sum_{i-1}^{k} \beta_i + \theta_1 + 2\theta_2 \ln M^* = 0. \quad (5)$$

Empirical Model: Stage Three

The third stage of the multiple budgeting framework is the decision of the households for allocation of fish expenditure on fish species i, conditional on the prices of all fish species/group under consideration, predicted per capita fish expenditure obtained from equation (4) normalized by the SPI of fish and the dummy variables for time (months), regions (districts), and consumer types.

We have instrumented the food expenditure term (M^*) in stage two and the fish expenditure term (F^*) in stage three by using their predicted values to resolve any measurement error problem related to fish consumption. Several authors including Blundell, Pashardes, and Weber (1993), Dey (2000), and Garcia, Dey, and Navarez (2005) have used the instrumental variable technique to remove the measurement error problem.

The estimation procedure for stage three of the model takes into account correction for the sample selection bias created by the presence of zero consumption of certain fish types in the data set. Following Dey (2000) and Garcia, Dey, and Navarez (2005), a Heckman two-step procedure was employed, where the Inverse Mill's Ratio (IMR) for the various fish types are first estimated and then incorporated in the estimation of the QUAIDS model. In the first step, a Probit regression is estimated, which determines the probability that a given household will consume the species in question. The decision to consume is modeled as a dichotomous choice problem (*e.g.*, $Y_i = 1$ if the i^{th} fish type is consumed; otherwise $Y_i = 0$; i = Indian carp, exotic carp, hilsa, assorted small fish, live fish, tilapia, shrimp and prawn, and high-valued species). Thus, for the i^{th} fish type, the probability that a given household will consume $P[Y_i = 1]$ is modeled as (the subscript for household is omitted for simplicity):

$$P[Y_i = 1] = f(P, F^*, R, T, C), \quad (6)$$

where P is a vector of prices of the different fish species/group including the i^{th} fish types; F^* is the predicted per capita fish expenditure obtained from equation (4); and R, T, and C are vectors of dummy variables as defined earlier. This probability is then used to compute the IMR for each household. The IMR incorporates the censoring of latent variables in the second step estimation of the demand relations.

The IMR is defined as:

$$\text{For } Y_i = 1 \qquad IMR_i = \phi\,(\mathrm{P}[Y_i = 1]) \,/\, \psi\,(\mathrm{P}[Y_i = 1]) \tag{7}$$

$$\text{For } Y_i = 0 \qquad IMR_i = \phi\,(\mathrm{P}[Y_i = 1]) \,/\, (1 - \psi\,(\mathrm{P}[Y_i = 1])), \tag{8}$$

where ϕ and ψ are density and cumulative probability functions, respectively.

In the second sub-step, share equations are then specified as a quadratic extension of the AIDS or QUAIDS model with the *IMR*s included as instrumental variables:

$$\begin{aligned} w_i = \tau_{i0} + \sum_{j-1}^{k} \mu_{ij} \ln P_j + \upsilon_{i1} \ln\left(F^*/P^*\right) + \upsilon_{i2} \ln\left[\left(F^*/P^*\right)\right]^2 + \ldots \\ + \sum_{j-1}^{3} \delta_{ij} R_j + \sum_{j-1}^{11} \varphi_{ij} T_j + \lambda_i C + \pi_i IMR_i + \varepsilon_i, \end{aligned} \tag{9}$$

where w_i are expenditure shares of the fish types *i*. The vector of prices (P_j) consists of the Stone-Lewbel (SL) cross-section prices[7] for the eight fresh fish species categories that are included in the study, namely: Indian carp, other carp, hilsa, tilapia, shrimp, assorted small fish, and other high-valued fishes. P^* is the SPI of fish, and F^*/P^* is the deflated predicted fish expenditure from the second stage, which is included in the model in linear and squared forms. The τ, μ, v, δ, φ, λ, and π are parameters to be estimated; the remaining variables are as defined earlier.

As expected, many of the 40 fish species considered in this article are substitutes. We tried to group these species into 6 to 10 categories and checked multicollinearity among the prices of the different species categories. We found that the eight fish categories described above are consistent with consumer behavior in Bangladesh and that multicollinearities between the different species categories are not significant. Given that the SL cross-section prices use varying weights across the population, they reduce the multicollinearity between the prices of different species categories.

The SPI allows the empirical approximation of the non-linear AIDS model to be linearly estimated. However, a number of papers (*e.g.*, Moschini 1995; Asche and Wessells 1997) have indicated that application of the Stone index introduces measurement errors, as it is not invariant to changes in units of measurement. Asche and Wessells (1997) suggested normalization of prices to 1.0 as a solution to this problem, but this approach holds only at a particular point. Given that our aim is to use QUAIDS to estimate elasticities for different economic groups in a particular country, it may not be problematic to use Stone's price index for our data set.

As in equation (5), the homogeneity conditions are imposed on the share equations. The homogeneity of degree zero in prices implies that consumers do not suffer from money illusion; they react to real, not nominal prices. Also, since the functions defined in equation (9) are systems of share equations, restrictions across equations (*i.e.*, the symmetry and adding-up) are also imposed. The symmetry restriction implies that the effect of a change in the price of fish type *i* on demand for fish type *j* is the same as the effect of

[7] Readers are referred to Hoderlein and Mihaleva (2008) for the details of Stone-Lewbel (SL) cross section prices. Following Lewbel (1989), who elaborates on an older idea, Stone, Holderlein, and Mihaleya (2008) have constructed SL cross-section prices exploring individual specific variation in the composition of the bundles of goods.

a change in the price of fish type j on the demand for fish type i (*i.e.*, $\mu_{ij} = \mu_{ji}$). Owing to the quadratic nature of the demand functions, the symmetry restriction also requires that the ratio of the coefficients income (v_{i1}) and its squared term (v_{i2}) must all be equal to a constant (say ϖ) for all i (*i.e.*, $\upsilon_{i1}/\upsilon_{i2} = \varpi$). The homogeneity and symmetry restrictions are shown in equations 10a and 10b below:

$$\text{Homogeneity}: \sum_{j=1}^{n} \mu_{ij} = 0, \tag{10a}$$

$$\text{Symmetry}: \mu_{ij} = \mu_{ji}, {}^{\nu_{11}}\!/_{\nu_{12}} = {}^{\nu_{21}}\!/_{\nu_{22}} = \ldots = {}^{\nu_{n1}}\!/_{\nu_{n2}} = \varpi. \tag{10b}$$

The adding-up restriction requires that the sum of the constants (τs) across equations (1) sums to unity, while the sum of the other parameters across equations is zero. The adding-up conditions imply a singular variance-covariance matrix for the disturbances if all the $k = 8$ demand equations are estimated jointly. The normal procedure is to delete one of the equations, since the parameters of that relation can be computed residually from the others by virtue of the formula of the adding-up restriction. The estimates are invariant to which good (species) is dropped. Hence, the equation for the live fish was arbitrarily dropped and the share equations were estimated by means of the Iterative Non-linear Seemingly Unrelated regression (ITSUR) method of the SYSNLIN procedure of SAS (SAS 1984).

Calculation of Elasticities

The relevant elasticities that were calculated include food expenditure elasticity with respect to income (η^y), fish expenditure elasticity with respect to food expenditure (η^f), fish expenditure elasticity for individual fish types (η_i), income elasticities of demand for an individual type of fish (η_i^y), and compensated (ξ_{ij}^H) and uncompensated (ξ_{ij}) price elasticities. They were computed according to Dey (2000) using the following formulas:

Food expenditure elasticity with respect to income (η^y):

$$\eta^y = \frac{\partial \ln M}{\partial \ln I} = \alpha_2 + 2\alpha_3 \ln I. \tag{11}$$

Fish expenditure elasticity with respect to food expenditure (η^f):

$$\eta^f = \frac{\partial \ln F}{\partial \ln M^*} = \theta_1 + 2\theta_2 \ln M^*. \tag{12}$$

Fish expenditure elasticity for individual fish types (η_i):

$$\eta_i = 1 + \left[\frac{\left(\partial \ln w_i / \partial \ln F^* \right)}{w_i} \right] = 1 + \left(\frac{\upsilon_{i1} + 2\upsilon_{i2} \ln F^*}{w_i} \right). \tag{13}$$

Income elasticity of demand for an individual type of fish:

$$\eta_i^y = \eta_i \cdot \eta^f \cdot \eta^y. \tag{14}$$

Uncompensated price elasticities:

$$\xi_{ij} = \left[\frac{\mu_{ij}}{w_i} \right] - \left[\frac{\partial w_i}{\partial \ln F^*} \right] \left(\frac{w_j}{w_i} \right) - k_{ij}, \tag{15}$$

where k_{ij} represents Kronecker delta, which takes the value of one for own-price elasticity (*i.e.*, $i = j$) and zero for cross-price elasticity (*i.e.*, $i \neq j$).

Compensated Hicksian Price elasticities:

$$\xi_{ij}^H = \xi_{ij} + w_j \eta_i. \tag{16}$$

Results and Discussion

Parameter Estimates of the Food and Fish Expenditure Equations

The estimated parameters of the food and fish expenditure functions are presented in tables 3 and 4, respectively. All variables, with the exception of some monthly and district dummy variables, were statistically significant. In the food expenditure equation (table 3), the price index of food (α_1) turned out to be a significant variable with a negative sign, indicating that higher food prices will result in lower expenditure for food commodities (that is, the decrease in demand is higher than the increase in price). The coefficient of per capita income (α_2) and its squared term (α_3) are significantly different from zero—the former being positive and the later being negative—indicating that the response of food expenditure to income change is non-linear with respect to the budget. As the budget for food progressively increases, the respective expenditure also tends to increase. It then reaches a maximum and ultimately declines. This implicitly captures the general behavior of consumers with respect to food consumption. Consumers have a certain threshold for food consumption; that is, once the threshold is reached, no amount of increased income can induce the consumer to purchase more food. Similar findings were also reported by Garcia, Dey, and Navarez (2005). The negative sign and significance of the coefficient of household size (α_5) implies that per capita food expenditure decreases with the increase of household size, *ceteris paribus*. The coefficient of the urban consumer type dummy (λ) is positive and statistically significant, indicating that their per capita food consumption expenditures are, on average, higher than the rural consumers, *ceteris paribus*.

Table 3
Parameter Estimates of the Food Expenditure Function

Variable	Estimates	Std. Error
Intercept	–4.302***	0.191
ln SPI of food	–0.676***	0.008
ln per capita income	3.757***	0.059
(ln per capita income)^2	–0.172***	0.004
ln non-food expenditure	–0.804***	0.010
Household size	–0.072***	0.001
Urbanity dummy	0.049***	0.004
January	0.028***	0.010
February	0.056***	0.010
March	0.067***	0.010
April	0.061***	0.010
May	0.042***	0.010
June	–0.061***	0.010
July	–0.004	0.010
August	0.006	0.010
September	–0.026***	0.010
October	–0.028***	0.010
November	0.004	0.010
Bagherpara and Jhikorgacha	0.001	0.006
Bogra Sadar and Sariakandi	0.131***	0.006
Trishal and Ishwarganj	0.001	0.006
RESTRICT	228.784***	2.981
R^2	0.75	
F-value	1,346.03***	

Note: Per capita food expenditure is the dependent variable.
*** significant at the 1% level.

Similar to the food expenditure equation, the two coefficients, food expenditure (θ_1) and its square term (θ_2) in the fish expenditure function, are significantly different from zero (table 4). The significance of the square term indicates that the response of fish expenditure to total food expenditure change is non-linear. The own-price parameter (β_1) is positive, which is unexpected. However, this is consistent with the results obtained and reported in Dey (2000). Fish expenditure is, on average, significantly higher (12%) among urban consumers when compared to rural consumers, *ceteris paribus*. Support for this explanation is shown in table 2. The results also provide support for the existence of seasonality of fish consumption. With other variables held constant, the results show that fish consumption is, on average, significantly higher during the first and third quarters of the year, as indicated by the pattern of the magnitude and signs of the coefficients of the monthly dummy variables (φ_i). In particular, the highest magnitude is observed in February and September, which are the peak months (figure 1). The signs of the coefficient for June and November are negative and significant, with June having the highest absolute value. During these two months, per capita fish consumption is lower than during the base month of December (figure 1).

Table 4
Parameter Estimates of the Fish Expenditure Function

Variable	Estimates	Std. Error
Intercept	–8.951***	1.249
ln Price of fish	1.652***	0.024
ln Price of cereal	–0.867***	0.048
ln Price of meat	–0.123***	0.031
ln Price of chicken	–0.549***	0.062
ln Price of eggs	–0.300***	0.035
ln Price of milk	–0.593***	0.041
ln Price of vegetables	–0.130***	0.016
ln Price of spice	–0.058***	0.016
ln Price of pulse	–0.176***	0.022
ln Price of oil	0.551***	0.030
[b] ln food expenditure	3.957***	0.418
[b] (ln food expenditure)^2	–0.282***	0.035
Household size	–0.117***	0.005
Urbanity dummy	0.115***	0.011
January	0.045*	0.025
February	0.219***	0.024
March	0.064**	0.024
April	0.103***	0.024
May	–0.001	0.024
June	–0.181**	0.025
July	0.015	0.025
August	0.199***	0.025
September	0.226***	0.024
October	0.017	0.025
November	–0.055**	0.024
Bagherpara and Jhikorgacha	–0.244***	0.016
Bogra Sadar and Sariakandi	–0.363***	0.019
Trishal and Ishwarganj	–0.400***	0.013
RESTRICT	48.713***	2.083
R^2	0.58	
F-value	440.55***	

Per capita fish expenditure is the dependent variable.
[b] Predicted values derived from stage one are used in estimation.
*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Parameter Estimates of the Fish Demand System of Equations

The estimated parameters of the fish demand system are presented in table 5. The coefficients of the square terms of per capita fish expenditure (v_2) are statistically significant different from zero, supporting the non-linear nature of specific type of fish expenditure. Most of the monthly and regional dummy variable coefficients are significant. The signs of these variables vary across species groups, indicating different preferences in fish consumption patterns of the consumers across the period and locality. The IMRs were all significant for all the equations. This implies that the inclusion of this variable in the QUAIDS model to correct for sampling bias brought about by zero purchase of some households for certain fish species proved to be worthwhile.

Table 5
Estimated Parameters of the Disaggregated Fish Demand System

	Indian Carp		Other Carp		Hilsa		Assorted Small Fish	
	Estimates	Std. Error	Estimates	Std. Error	Estimates	Std. Error	Estimates	Std. Error
Intercept	0.388***	0.013	0.534***	0.012	0.217*	0.01	0.693***	0.013
ln Price of Indian carp	0.156***	0.01	–0.075***	0.007	–0.014**	0.006	–0.015***	0.006
ln Price of other carp	–0.075	0	0.136***	0.008	–0.016***	0.005	–0.033**	0.006
ln Price of hilsa	–0.014***	0.012	–0.016***	0.005	0.041***	0.008	–0.029***	0.005
ln Price of assorted small fish	–0.015***	0.007	–0.033**	0.006	–0.029***	0.005	0.161***	0.008
ln Price of high-valued fish	–0.054***	0.008	–0.041***	0.004	0.028***	0.004	0.016***	0.003
ln Price of tilapia	–0.010***	0.003	–0.023***	0.004	0.001	0.004	0.02***	0.004
ln Price of shrimp and prawn	0.001*	0.01	0.037***	0.004	–0.002	0.004	–0.077***	0.004
[a] ln Price of live fish	0.01		0.013		–0.009		–0.044	
[a,b] ln real per capita fish expenditure	0.021		–0.140		0.044		–0.212	
[b] (ln real per capita fish expenditure)^2	–0.001***	0.008	0.005***	0.003	–0.002*	0.001	0.007*	0.004
Household size	0.007***	0.002	–0.025***	0.001	0.007***	0.001	–0.035***	0.002
Urban consumer dummy	–0.010***	0.003	0.004	0.003	–0.006***	0.002	0.006*	0.004
January	–0.003	0.008	0.02***	0.007	0.049***	0.005	–0.008	0.008
February	–0.035***	0.008	0.04***	0.007	0.027***	0.005	0.036***	0.008
March	–0.038***	0.008	0.013*	0.007	0.033***	0.005	0.014*	0.008
April	–0.055***	0.008	0.033***	0.007	0.048***	0.005	–0.003	0.008
May	–0.036***	0.008	0.031***	0.007	0.039***	0.005	–0.007	0.008
June	0.013*	0.008	–0.009	0.007	0.055***	0.005	–0.036***	0.008
July	–0.046***	0.008	–0.022***	0.007	0.058***	0.005	0.029***	0.008
August	–0.047***	0.008	0.012*	0.007	0.07***	0.005	0.115***	0.008
September	–0.056***	0.008	0.01	0.007	0.086***	0.005	0.117***	0.008
October	–0.059***	0.008	–0.003	0.007	0.06***	0.005	0.067***	0.008
November	–0.052***	0.008	–0.015**	0.007	0.034***	0.005	0.024***	0.008
Bagherpara & Jhikorgacha	–0.032***	0.005	–0.080***	0.004	0.07***	0.003	–0.078***	0.005
Bogra Sadar & Sariakandi	–0.008*	0.005	–0.019***	0.004	0.005*	0.003	–0.080***	0.005
Trishal & Ishwarganj	–0.012**	0.005	–0.067***	0.005	0.045***	0.003	–0.084***	0.005
IMR	–0.262***	0.004	–0.206***	0.004	–0.348***	0.004	–0.186***	0.006
Lambda (constant ratio)	–28.47*	15.96						

[a] Significance cannot be estimated since these parameters are generated through homogeneity, adding-up, and symmetry restrictions.
[b] Predicted values derived from stage two are used in estimation.
*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Table 5 (continued)
Estimated Parameters of the Disaggregated Fish Demand System

	High-Valued Fish		Tilapia		Shrimp and Prawn		Live
	Estimates	Std. Error	Estimates	Std. Error	Estimates	Std. Error	Fish[a]
Intercept	0.501***	0.008	0.34***	0.007	0.272***	0.01	–1.945
ln Price of Indian carp	–0.054***	0.004	–0.010**	0.004	0.001	0.005	0.01
ln Price of other carp	–0.041***	0.004	–0.023***	0.004	0.037***	0.004	0.013
ln Price of hilsa	0.028***	0.004	0.001	0.004	–0.002	0.004	–0.009
ln Price of assorted small fish	0.016***	0.003	0.02***	0.004	–0.077***	0.004	–0.044
ln Price of high-valued fish	–0.040***	0.004	0.026***	0.003	–0.012***	0.003	0.077
ln Price of tilapia	0.026***	0.003	<0.001	0.005	–0.002	0.003	–0.012
ln Price of shrimp and prawn	–0.012***	0.003	–0.002	0.003	0.104***	0.004	–0.049
[a] ln Price of live fish	0.077		–0.012		–0.049		0.015
[a,b] ln real per capita fish expenditure	0.051		–0.028		0.12		0.145
[b] (ln real per capita fish expenditure)^2	–0.002*	0.001	0.001*	0.001	–0.004*	0.002	–0.005
Household size	0.003***	0.001	–0.009***	0.001	0.01***	0.001	
Urban consumer dummy	0.001	0.001	0.003*	0.002	–0.021***	0.002	
January	0.01***	0.003	–0.011***	0.004	0.002	0.005	
February	0.015***	0.003	–0.014***	0.004	–0.020***	0.005	
March	0.018***	0.003	–0.022***	0.004	0.018***	0.005	
April	0.016***	0.003	–0.007*	0.004	0.017***	0.005	
May	0.027***	0.003	–0.017***	0.004	0.024***	0.005	
June	–0.031***	0.003	–0.015***	0.004	0.039***	0.005	
July	–0.035***	0.004	–0.021***	0.004	0.022***	0.005	
August	–0.032***	0.003	–0.017***	0.004	–0.083***	0.005	
September	<0.001	0.003	–0.024***	0.004	–0.069***	0.005	
October	0.022***	0.003	–0.021***	0.004	–0.021***	0.005	
November	0.009***	0.003	–0.012***	0.004	0.01**	0.005	
Bagherpara and Jhikorgacha	–0.047***	0.002	–0.012***	0.002	0.077***	0.003	
Bogra Sadar and Sariakandi	–0.014***	0.002	0.012***	0.002	–0.019***	0.003	
Trishal and Ishwarganj	–0.032***	0.002	–0.013***	0.003	0.047***	0.003	
IMR	–0.572***	0.005	–0.252***	0.003	–0.450***	0.005	

[a] Significance cannot be estimated since these parameters are generated through homogeneity, adding-up, and symmetry restrictions.
[b] Predicted values derived from stage two are used in estimation.

Elasticities Calculated at Various Stages of Estimation

Food and fish expenditure elasticities calculated at various stages of estimation are presented in table 6. Food expenditure elasticity with respect to total income (η^y) was estimated in the first-stage estimation, while fish expenditure elasticity with respect to food expenditure (η^f) was estimated from the second-stage estimation. Fish expenditure elasticities for individual fish types (η_i) were estimated from the third-stage estimation. In addition to national average elasticities, elasticities at different levels of income are also estimated. Food expenditure elasticities with respect to income are positive and elastic *(i.e.*, $\eta^y > 1$) for all the quartile groups. The overall food expenditure elasticity was found to be at 1.48. The food expenditure elasticities decline from 1.67 to 1.23 as income rises. This suggests that food expenditure, in general, elicits higher responses among the poor and the middle classes when income increases. Fish expenditure elasticity with respect to food expenditure (η^f) shows the same declining pattern. However, fish expenditure elasticities are all inelastic *(i.e.*, $\eta^f < 1$) indicating that fish is a necessary commodity among consumers in inland areas of Bangladesh. The declining magnitudes of fish expenditure elasticities across income quartile groups indicate that with a higher food budget, poorer households will respond more in terms of fish expenditures than richer households. Fish-specific elasticities of demand with respect to total fish expenditure (η_i) vary across fish types and income groups. Except for tilapia, η_i decreases as income increases.

Table 6
Estimated Income Elasticities of Demand for Fish

	Income Groups				
Elasticities at Different Stages	Quartile-1	Quartile-2	Quartile-3	Quartile-4	Overall
A. Food expenditure elasticity with respect to total income (Stage I)	1.67	1.55	1.47	1.23	1.48
B. Fish expenditure elasticity with respect to food expenditure (Stage II)	0.76	0.64	0.54	0.44	0.59
C. Species-specific fish expenditure elasticity (Stage III)					
Indian carp	1.10	1.09	1.08	1.08	1.09
Other carp	0.32	0.25	0.27	0.29	0.28
Hilsa	1.48	1.42	1.47	1.41	1.44
Assorted small fish	0.22	0.09	0.03	–0.11	0.07
High-valued fish	3.05	2.10	1.96	1.91	2.14
Tilapia	0.41	0.33	0.45	0.59	0.46
Shrimp and prawn	2.90	2.77	3.30	2.79	2.92
Live fish	2.94	2.48	2.33	2.41	2.51

Uncompensated/Compensated Own-price Elasticities of Demand for Fish

The uncompensated elasticity of demand (ξ_{ij}) refers to changes in the quantity of fish demanded as a result of price changes in the absence of any compensation in terms of either price or income change. Put simply, this represents the general price elasticities of demand. On the other hand, the compensated elasticity of demand for fish (ξ_{ij}^{H}) refers to that portion of the total change in the quantity of fish demanded which is compensated by price changes. Once the allowance for price compensation to the total change in the quantity demanded (of the uncompensated elasticities) is made, the remaining is the income effect. That is, price effect plus income effect equals the total effect.

The uncompensated (ξ_{ii}) and compensated (ξ_{ii}^{H}) own-price elasticities of demand for aggregated and disaggregated species of fish in Bangladesh are presented in table 7. All own-price elasticities (uncompensated and compensated) display appropriate negative signs, indicating the negative relationship between prices of a normal commodity and its demand. A substantial difference between compensated and uncompensated own-price elasticities is observed, indicating a substantial effect of income. The magnitudes of elasticities vary across different species and quartile groups, indicating the relevance of species and quartile-specific estimation. Compensated own-price elasticities are, in general, lower than the uncompensated elasticities. This implies that price responsiveness of the different fish types is dependent on income; when income is held constant (*i.e.*, it is not a constraint in the decision process), consumers tend to be less responsive to fish prices.

Table 7
Own-price Elasticities of Different Types of Fish

Expenditure	Fish							
Quartile	Indian Carp	Exotic Carp	Hilsa	Assorted Small Fish	High-Valued Fish	Tilapia	Shrimp and Prawn	Live Fish
				Uncompensated own-price elasticity				
First	–0.31	–0.19	–0.60	–0.20	–2.66	–0.97	–1.15	–0.94
Second	–0.36	–0.12	–0.65	–0.08	–1.93	–0.97	–1.14	–0.98
Third	–0.40	–0.13	–0.59	–0.03	–1.82	–0.97	–1.15	–1.00
Fourth	–0.37	–0.15	–0.65	0.08	–1.79	–0.97	–1.14	–0.99
Overall	–0.36	–0.15	–0.62	–0.07	–1.96	–0.97	–1.14	–0.98
				Compensated own-price elasticity				
First	–0.07	–0.13	–0.46	–0.14	–2.58	–0.95	–0.96	–0.72
Second	–0.10	–0.07	–0.50	–0.07	–1.84	–0.95	–0.96	–0.75
Third	–0.13	–0.08	–0.46	–0.03	–1.72	–0.94	–0.98	–0.75
Fourth	–0.11	–0.09	–0.50	0.06	–1.69	–0.93	–0.96	–0.75
Overall	–0.10	–0.10	–0.48	–0.06	–1.86	–0.94	–0.97	–0.75

The uncompensated own-price elasticities of Indian carp, exotic carp, hilsa, assorted small fish, tilapia, and live fish were inelastic (*i.e.*, $\xi_{ii} < 1$), while those of shrimp and prawn and high-valued fish were demand elastic (*i.e.*, $\xi_{ii} > 1$). The uncompensated own-price elasticity estimates for Indian carp, exotic carp, and assorted small fish indicate that price increase results in a very small decline in their demand. This behavior is probably a reflection of the fact that all consumer types in the country normally consume these species. The uncompensated elasticity estimates for assorted small fish are the lowest, indicating that the proportionate decrease in their demand is much lower than other species as price increases. These price elasticity estimates differ considerably from those estimated using the Household Expenditure Survey (HIES) data of the BBS. For example, most of the estimates made by Goletti (1992) and Dey (2000), both of whom had made use of the same HIES data of 1988–89, are higher than one and elastic. Using the 1991–92 HIES data, Razzaque, Khondoker, and Mujeri (1997) estimated own-price elasticities of demand for fish to be in the range from 0.09 to 1.01 for different types of consumers. Cross sectional estimates, however, are lower than 1.0 (see Ahmed and Shams 1994).

Compensated Cross-price Elasticities

In general, cross-price elasticity of demand for fish (ξ_{ij}^{H}) refers to the changes in the quantity demanded of one species as a result of changes in prices of others. Cross-price elasticities of several relations for different income quartile groups are presented in table 8. By virtue of symmetry, only the lower diagonal values are reported here. The elasticities on the main diagonal represent own-price elasticity (ξ_{ii}^{H}). For brevity, only the figures for the first and fourth quartile groups are reported in the table. Most of the ξ_{ij}^{H} across different quartile groups are inelastic (*i.e.*, $\xi_{ij}^{H} < 1$). However, the cross-price relationships involving high-valued fish are elastic (*i.e.*, $\xi_{ij}^{H} > 1$). There is also evidence of substitutability (*i.e.*, $\xi_{ij}^{H} > 0$) and complementarity (*i.e.*, $\xi_{ij}^{H} < 0$) among the different cross pairs, especially among the lower income groups. Figures with the positive (negative) algebraic signs indicate substitutability (complementarity). Eleven of the 28 figures in the first quartile and 10 of the 28 in both the second quartile and the overall average had negative signs indicating complementarities.

Income Elasticities of Demand for Fish

Responses to fish demand with an increase in income differs considerably across different income quartiles and fish types (table 9). As expected, income elasticities of demand (η_i^y) for relatively expensive fish, such as live fish, high-valued species, shrimp and prawn, hilsa, and to some extent Indian carp, are elastic (*i.e.*, $\eta_i^y > 1$). Similar findings were also reported by Razzaque, Khondoker, and Mujeri (1997). With all fish types, the rate of increase of fish expenditure declines as income increases. Indian carp, which are the most common fish species in the country and the entire south Asian region, are luxury species among the lower-income groups, while they are a necessity among higher-income groups and average consumers. Hilsa, high-valued species, shrimp and prawn, and live fish appear to be luxury commodities among the lower income groups. Assorted small fish is a necessary commodity (with income elasticity $0 < \eta_i^y < 1$) for the lower-income groups and is an inferior good (*i.e.*, $\eta_i^y < 0$) for the richest quartile. All these suggest that fish consumption among the lower-income groups responds more to changes in income than consumption among those belonging to higher-income groups, *ceteris paribus*.

Table 8
Cross-price Elasticities of Different Types of Fish

Fish Type	Indian Carp	Exotic Carp	Hilsa	Assorted Small Fish	High-Valued Fish	Tilapia	Shrimp and Prawn	Live Fish
				Expenditure Quartile I				
Indian carp	–0.07							
Exotic carp	–0.13	–0.13						
Hilsa	0.03	0.02	–0.46					
Assorted small	0.20	0.11	–0.05	–0.14				
High-valued fish	–0.22	–0.17	0.33	0.09	–2.58			
Tilapia	0.00	–0.06	0.06	0.12	1.08	–0.95		
Shrimp and prawn	0.07	0.24	0.04	–0.22	–0.42	0.03	–0.96	
Live fish	0.12	0.14	–0.03	–0.09	3.15	–0.18	–0.71	–0.72
				Expenditure Quartile 4				
Indian carp	–0.11							
Exotic carp	–0.12	–0.09						
Hilsa	0.05	0.02	–0.50					
Assorted small	0.12	0.01	–0.10	0.06				
High-valued fish	–0.17	–0.16	0.33	0.14	–1.69			
Tilapia	0.02	–0.05	0.08	0.18	0.54	–0.93		
Shrimp and prawn	0.07	0.26	0.05	–0.36	–0.16	0.04	–0.96	
Live fish	0.14	0.17	0.01	–0.14	1.52	–0.09	–0.67	–0.75
				Overall Average				
Indian carp	–0.10							
Exotic carp	–0.12	–0.10						
Hilsa	0.04	0.02	–0.48					
Assorted small	0.16	0.05	–0.08	–0.06				
High-valued fish	–0.18	–0.17	0.33	0.12	–1.86			
Tilapia	0.01	–0.07	0.06	0.14	0.63	–0.94		
Shrimp and prawn	0.07	0.25	0.04	–0.28	–0.21	0.03	–0.97	
Live fish	0.14	0.16	0.00	–0.10	1.84	–0.15	–0.72	–0.75

Table 9
Income Elasticities of Different Types of Fish

	Types of Fish							
Expenditure Quartile	Indian Carp	Exotic Carp	Hilsa	Assorted Small Fish	High-Valued Fish	Tilapia	Shrimp and Prawn	Live Fish
First	1.39	0.40	1.88	0.28	3.86	0.52	3.67	3.73
Second	1.07	0.25	1.40	0.08	2.08	0.33	2.74	2.45
Third	0.86	0.21	1.17	0.02	1.55	0.36	2.61	1.84
Fourth	0.59	0.16	0.76	–0.06	1.03	0.32	1.51	1.31
Overall	0.95	0.25	1.27	0.06	1.88	0.41	2.56	2.21

Concluding Remarks and Policy Implications

The results of this research show that elasticities of demand for fish in Bangladesh vary substantially across species and income groups. This only proves that fish is not a homogeneous commodity and the disaggregated level of analysis appears more appropriate. It is, therefore, very important to estimate fish demand elasticities specific to species and income groups. The findings have several important policy implications.

First, almost all (31 of 32) estimated fish-type and income-class specific income elasticities of demand are positive. Thus, with an increase in population and per capita income, the demand for various types of fish in Bangladesh will increase. Second, the estimated income elasticities for all fish types tend to be higher among poorer households compared to the more affluent members of society. This analysis indicates that there will be substantial increases in fish demand in Bangladesh; a major share of which is expected to come from poorer households with increasing income. Absence of commensurate increases in fish supply will increase fish prices. Third, price elasticity of demand for carp (both Indian and exotic) is inelastic. With carp producers facing inelastic demand for fish on the domestic market, increased investment in the carp sector should be carefully monitored. An increase in carp supply is likely to result in a fall in farmers' revenue. However, the fall in carp price will be beneficial to carp consumers. Subsistence carp farmers will also be able to internalize some of the consumers' benefit resulting from the decline in prices. Fourth, demand for high-valued fish (including *Pangas*) and shrimp are price elastic. This indicates that an increase in supply of *Pangas* and shrimp and prawn is likely to increase farmers' revenue. Fifth, technological improvement in the culture of tilapia, whose uncompensated own-price elasticity of demand is around –1, is expected to moderately decrease the price of tilapia and increase the welfare of both producers and consumers.

The empirical results are reasonable and have provided new information about the demand for fish in a developing Asian country where fish is the main source of animal protein. The results are important for future modeling and analysis of the aquaculture and fisheries sector in Bangladesh. Information on disaggregated price and income elasticity estimates will be valuable for policy planners, particularly in considering future investment and development in the aquaculture and fisheries sector.

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