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Drivers of the Bangladesh Fish Economy

Projections of Future Fish Supply and Demand

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Contents

Tables

Figures

ABSTRACT

Fish play a major role in the Bangladesh food system. Fish production, processing and marketing are major source of incomes for many households, and fish consumption accounts for a significant share of protein consumption in the Bangladeshi diet. Moreover, fish production and consumption are growting rapidly, with the aquaculture subsector as a major driver of change of both supply and demand

In this paper, we present estimates of demand elasticities for four categories of fish (aquaculture, inland capture, mixed production, and marine) using a modified Quadratic Almost Ideal Demand System. These demand estimates are then used in projections of future supply and demand for these different types of fish under different productivity growth assumptions. Our results show that, at current rates of productivity increase, growth in fish production will outpace increases in demand from population and income growth, resulting a decline in real prices over time. A more rapid increase in productivity would lead to even larger supply increases and corresponding price declines. These effects are most keenly felt by the poorest households who see significant increases in fish consumption. Fish production from aquaculture is likely to have higher rates of productivity growth than the more extensive inland capture and marine systems, leading to a long term shift increase in the share of aquaculture production and consumption.

Keywords: Bangladesh, fish economy, aquaculture, Quadratic Almost Ideal Demand System (QUAIDS), multimarket model

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ACRONYMS

BBS	Bangladesh Bureau of Statistics
CPI	Consumer Price Index
EU	European Union
GDP	Gross Domestic Product
HIES	Household Income Expenditure Survey
QUAIDS	Quadratic Almost Ideal Demand System

1. INTRODUCTION

The Bangladesh fish sector has experienced both rapid growth and rapid change in the past several decades. With plentiful waterways, access to the sea, and a subtropical climate, prospects for future production growth are equally bright. Domestic demand for fish products is also increasing as rising incomes and more efficient value chains make fish products more accessible and affordable for both rural and urban households. How fast supply grows relative to demand will determine not only future movements in real prices of fish products, but also the feasibility of significant levels of exports.

Our analysis of future production trends involves modeling of different growth rates of the various fish production systems: inland capture, aquaculture and marine fisheries. Recently, aquaculture development has been stressed by both private and public sector organizations (FAO 2014). Indeed, aquaculture productivity has increased, though this has not been the case for other fishery systems such as inland capture and marine fisheries. All these systems are beset with their own constraints but also have unique opportunities to contribute to future growth.

The analysis of future demand is based on econometric estimates of own price and expenditure elasticities for four different fish groups using a modified Quadratic Almost Ideal Demand System (QUAIDS). Elasticities are estimated within rural and urban household groups, and within these subsets, poor and nonpoor. These parameters are then used, along with other exogenous parameters, in a multimarket model. Using this model, we can then provide a baseline estimation of future fish production, demand and prices. We also model the effects of hypothetical shocks to fish production to investigate their impacts on the fish economy.

The plan of the chapter is as follows. The next section provides a brief overview of fish production systems in Bangladesh along with their historical trends. The following section discusses the estimation of demand parameters, including the equations and variables used, and the empirical results. Thereafter, we provide a description of the multimarket model and the other parameters involved, along with the results of the baseline estimations and the policy simulations. The final section concludes.

2. FISH PRODUCTION SYSTEMS

There are three primary systems of fish production in Bangladesh: aquaculture, inland capture, and marine capture. Each of these systems has its own unique trend and faces unique constraints. We discuss each of them briefly below to provide context for the later analysis.

Aquaculture

There are a variety of aquaculture methods practiced in Bangladesh, from cage production to the use of floodplains. However, by far the dominant method is that of pond culture, accounting for nearly 86 percent of total aquaculture. The two main pond culture methods are "homestead pond culture" and "entrepreneurial pond culture". Homestead farm culture has developed from small ponds used by individual households to supplement consumption and sometimes income. These are often not the primary source of income for a household, but have accounted for increasingly large shares of income over the past few years. A major constraint for these types of ponds is low productivity, though opportunities to raise productivity through improved practices exist. Numerous development projects have been implemented in recent years, but to date the results have been mixed, with slow uptake of new technology, leading to relatively small productivity gains (Belton et al. 2011, Bloomer 2012).

"Entrepreneurial ponds" are those which have been started with the expressed intent of being a primary source of income. These ponds produce at much larger scales, requiring greater access to inputs markets and labor (Belton et al. 2011). Entrepreneurial ponds face constraints as well. Access to finance is one of these, as farmers find it difficult to reliably find loans and other sources of capital (Bloomer 2012). And although improvements in seed and input markets have contributed to recent growth in aquaculture, low access to inputs still represents a key constraint in further improvements. Competition for space and resources with agriculture is also a concern (FAO 2014).

Inland Capture

Inland capture production covers the more traditional fishing systems involving the capture of wild fish from streams, rivers, and lakes. Inland fisheries often either do not use boats, or only utilize small, nonmotorized boats, or are small–scale. The types of various freshwater fish (including barbs, tilapia, climbing perch, and medium catfish) produced from inland capture have long been a staple in the Bangladeshi diet and are often preferred by the local population to fish produced via aquaculture (FAO 2014). However, production in this sector has clearly begun to lag that of aquaculture ponds.

The main constraints facing inland capture are habitat loss (due to urbanization and agricultural intensification), pollution leading to environmental stress, and over-exploitation of the resources (Belton et al. 2011). Recurring floods and natural disasters have also led to major losses of habitats. In particular, the recent series of intense floods have degraded portions of traditional inland capture fisheries. These disasters are only expected to become more frequent due to climate change, to which Bangladesh is particularly vulnerable (Ghose 2014).

Marine

Finally, marine production refers to all fish production coming out of marine fisheries. As with inland capture, it is mostly dominated by small scale fisheries (in this case, using boats), however, there are also a semi-industrialized fishery sector and a small industrial sector (FAO 2014).

A significant constraint facing marine fishing is that of over-fishing. Exploitive fishing practices have hindered long and short-term prospects as have challenges in establishing co-management areas (Ghose 2014). Another constraint facing marine fishing, according to Belton et al. (2011) is difficult meeting international standards for the products. Marine fish (especially shrimp) producers have struggled to maintain the quality standards demanded by most large importers of shrimp, including the United States. Maintaining these standards would provide a significant boon to the viability of marine production exports.

In July of 1997, the European Union (EU) banned imports of fish produced in Bangladesh (most Bangladesh fish exports are from marine fisheries). The ban was initiated due to EU inspections of Bangladeshi fish processing plants. The plants were found to be in serious violation of EU standards for seafood products and lacking in quality controls. Overall, the ban is estimated to have cost Bangladesh US$ 15 million in just 5 months. In the subsequent years, Bangladesh addressed the issues that led to the ban, and exports to the EU began to open up again. However, with ever changing quality standards, it will continue to be an issue that must be consistently re-evaluated (Cato and Subasinge 2003).

Historical Trends

Aquaculture has become increasingly prominent in the fish production mix of Bangladesh over the last 15 years. According to Bangladesh Bureau of Statistics (BBS) data, aquaculture's share of fish production increased from 30 percent to 47 percent from 2000 to 2015. As well, the Household Income Expenditure Survey (HIES) data shows a kilogram per capita increase of 3.3 to 7.2 from 2000 to 2010.

Table 2.1 below shows production levels for 2010 which are estimated from the shares of consumption of various types of freshwater fish from the 2010 HIES multiplied by the 2010 total fresh water fish production figures from BBS. Since BBS disaggregates production into only two categories (aquaculture and inland capture), growth rates for the three categories shown in this table (aquaculture, mixed and inland capture), differ from the BBS production figure growth rates. (Definitions of marine fish are consistent across both the BBS and HIES.)

Table 2.1: Bangladesh: Historical production trends (thousand metric tons)

Year	Aquaculture	Inland capture	Mixed	Marine	Total
2000	498	369	460	334	1,661
2001	541	372	395	379	1,688
2002	588	375	512	415	1,890
2003	638	378	550	432	1,998
2004	693	381	573	455	2,102
2005	753	384	605	475	2,216
2006	818	387	645	480	2,329
2007	888	389	675	487	2,440
2008	964	392	709	498	2,563
2009	1,047	395	744	515	2,701
2010	1,138	398	846	517	2,899
2011	1,235	401	832	546	3,015
2012	1,342	404	987	579	3,312
2013	1,457	408	956	589	3,410
2014	1,583	411	945	595	3,534
2015	1,719	414	934	600	3,667
Annual growth rates					
2000–2005	8.6%	0.8%	5.6%	7.3%	5.9%
2005–2010	8.6%	0.8%	6.9%	1.7%	5.5%
2010–2015	8.6%	0.8%	2.0%	3.0%	4.8%
2000–2015	8.6%	0.8%	4.8%	4.0%	5.4%

Note: Historical production trends were calculated by estimating the “mixed” category proportion based on HIES 2010 data, adjusting backwards to 2000 using the 2005–2010 growth rate, and then projecting forward using the 2010–2015 growth rate.

Source: BBS (2000, 2005, and 2010), HIES (2010), and Authors' Calculations

Estimates of production for aquaculture and inland capture for 2000 were constructed using our 2010 production estimates and the 2005–2010 BBS production growth rates for these categories; mixed system production was estimated as the residual. Figures for production of aquaculture and inland capture for 2000 to 2015 are estimated using the calculated figures for levels of production in 2000 and the historical growth rate of these categories from 2010–2015 as calculated from BBS production data.

The table shows just how rapid aquaculture growth has been as compared to the three other fish categories. The fourth type of fish production system called “mixed” contains the fish consumed in the HIES data which we could not accurately account for being produced via aquaculture or inland capture due to the heterogeneous systems used to produce some types of fish.[1]

Aquaculture production has grown from 498 thousand tons to over 1,700 in the 15 years shown in the table. Inland capture only grew from 369 thousand tons to 414. Mixed and marine categories grew more than did

[1] The categorization of the fish was taken from Toufique and Belton, 2014. A table A.4 with the full breakdown can be found in Annex II. Their categorization classifies shrimp as inland capture rather than marine – we will follow this for the further analysis.

inland capture but both did not nearly achieve the same levels of growth as that of aquaculture.

These levels of growth are mirrored by the annual growth rates shown below them. Aquaculture had an annual growth rate of nearly 9 percent for the 15-year period in question, while growth in inland capture was less than one percent. Growth in marine fish production has likewise been slow, although growth accelerated slightly after 2010.

The consumption data from the HIES, shown below in Table 2.2, mirrors this pattern of the increasing importance of aquaculture and the decreasing importance of inland capture. In both rural and urban areas, aquaculture fish consumption increased faster than fish consumption from other production systems, from 3.76 kg/capita in 2000 to 7.41 kg/capita in 2010 in urban areas. Meanwhile, per capita consumption of inland capture system fish declined, from 3.47 to 3.15 kg/capita in urban areas. In the other two categories, mixed sees some increase (to be expected given it contains some aquaculture), and marine slightly declines in rural areas and slightly increases in urban areas (again expected since it is somewhat of a luxury item).

Table 2.2: Bangladesh: Historical fish consumption trends

	2000		2005		2010	
	Rural	Urban	Rural	Urban	Rural	Urban
Kg per capita						
Aquaculture	3.21	3.76	5.12	5.79	7.10	7.41
Mixed	4.38	3.82	4.95	4.57	5.07	6.27
Inland capture	3.58	3.47	2.64	3.31	2.33	3.15
Marine	1.76	3.41	1.42	3.91	1.51	4.36
Total fish	*12.92*	*14.46*	*14.14*	*17.57*	*16.01*	*21.19*
Consumption value shares						
Aquaculture	3.1%	3.7%	4.0%	4.5%	5.4%	5.2%
Mixed	4.0%	3.6%	3.9%	3.8%	4.2%	4.8%
Inland capture	3.5%	3.5%	2.4%	3.0%	2.0%	2.6%
Marine	2.1%	3.5%	1.8%	3.6%	2.0%	4.4%
Total fish	*12.7%*	*14.3%*	*12.2%*	*14.9%*	*13.6%*	*16.9%*

Note: Per capita kg are per year

Source: Authors' calculations from Bangladesh HIES 2000, 2005, and 2010.

Turning to value shares, in 2000, urban areas consumed a larger share of aquaculture relative to total consumption than did the rural areas, but by 2010 the rural areas were consuming a larger share of aquaculture. This is most likely due to the expanding production, and lower prices (seen below in Table 2.3). Urban areas also see much higher rates of consumption for marine fish, which, per the HIES data, are the most expensive of the fish produced in Bangladesh.

Table 2.3: Bangladesh: Historical fish price trends

Major group	Fish name	2010 value weights	Price indices			%Δ '00 to '05	%Δ '05 to '10	%Δ '00 to '10
			2000	2005	2010			
Aquaculture	Rhui/ Katla/ Mrigel/ Kal baush	35%	0.960	0.812	1.000	-19%	23%	4%
	Silver carp/ Grass carp/ Miror carp	30%	0.954	0.777	1.000	-22%	29%	5%
	Pangash/ Boal/ Air	34%	1.484	0.909	1.000	-9%	10%	-33%
	Total primarily agriculture		*1.138*	*0.835*	*1.000*	*-17%*	*20%*	*-12%*
Mixed	Kai/ Magur/ Shinghi/ Khalisha	5%	0.758	0.681	1.000	-32%	47%	32%
	Koi	8%	0.481	0.688	1.000	-31%	45%	108%
	Mala–kachi/ Chala–chapila	26%	0.855	0.769	1.000	-23%	30%	17%
	Puti/ Big Puti/ Telapia/ Nilotica	60%	0.851	0.765	1.000	-24%	31%	17%
	Total mixed		*0.816*	*0.755*	*1.000*	*-24%*	*32%*	*23%*
Inland capture	Shoal/ Gajar/ Taki	25%	0.803	0.745	1.000	-25%	34%	25%
	Tangra/ Eelfish	12%	0.695	0.694	1.000	-31%	44%	44%
	Baila/ Tapashi	3%	0.808	0.781	1.000	-22%	28%	24%
	Shrimp	40%	0.649	0.669	1.000	-33%	50%	54%
	Other	19%	0.748	0.725	1.000	-27%	38%	34%
	Total inland capture		*0.718*	*0.706*	*1.000*	*-29%*	*42%*	*39%*
Marine	Hilsa	35%	0.623	0.652	1.000	-35%	53%	61%
	Dried fish	51%	0.693	0.693	1.000	-31%	44%	44%
	Sea fish	14%	0.873	0.714	1.000	-29%	40%	15%
	Total marine		*0.693*	*0.682*	*1.000*	*-32%*	*47%*	*44%*

Note: Price indices are in real terms where 2010 = 100. Scientific names for all fish are listed in Table A.5

Source: Authors' calculations from Bangladesh HIES 2000, 2005, and 2010.

Finally, price indices for the four types of fish production from 2000 to 2010 are presented in Table 2.3. These price indices were calculated using weights based on household expenditure shares in the 2010 HIES. We use the consumer price index (CPI) as a price deflator to convert all prices to real 2010 prices. For purposes of presentation, however, we rescale the indices such that 2000 = 100. As shown, prices of fish from most of the production systems have increased over time, with real prices of fish from mixed, inland capture and marine systems rising by 23, 39 and 44 percent, respectively. Prices of fish produced in aquaculture systems declined by 12 percent, however, reflecting an increase in supply relative to demand.

3. DETERMINANTS OF FISH DEMAND

Economic Specification

To obtain expenditure and price elasticities for the simulations, we estimate a QUAIDS model using data from the Bangladesh HIES in the years 2000, 2005, and 2010. These surveys contain household level data on incomes, assets, and, most importantly to our study, expenditures on food and durable/nondurable goods. The main variables of interest were those of quantity of items consumed, total expenditures on items, and price (which was imputed from the total expenditure and quantity consumed of each item).[2] The 2000 HIES covers 7,440 households (5,040 rural and 2,400 urban), while the 2005 covers 10,080 (6,400 rural and 3,680 urban), and the 2010 covers 12,240 (7,840 rural and 4,400 urban).

A three-stage methodology was used for the analysis, adapted from Ecker and Qaim (2010). The first stage estimates the elasticity for food versus nonfood. This eliminates the need for predicting missing nonfood prices, but relies on the assumption that consumption decisions are first made by the individual at a food versus nonfood level, rather than nonfood versus any particular food category. The second stage estimates the elasticities within the six major food groups of the study, and the third stage estimates within the four different types of fish. Again, the assumption is that consumption decisions are more likely to be made within these smaller groups than across them. Unconditional elasticities were then calculated using the estimates from the three stages.

The households in the sample were divided into rural and urban subgroups, and the methodology was applied separately within these groups. This was done with the idea that the rural and urban samples would most likely differ in their responses to price and expenditure changes. Full sample estimates were potentially troublesome due to excessive heterogeneity within the sample. As such, full sample elasticities were calculated by adding up the quantity weighted elasticities of the two smaller samples. Elasticities were also calculated, within the rural and urban samples, at the means for the bottom three and top two quintiles of expenditure (these will be referred to as poor and non-poor in later tables). Standard errors for the

[2] Outliers for quantity and expenditure observations were defined as those outside of five standard deviations from the mean, within each category and were removed from the final sample.

elasticities estimation were calculated via bootstrapping at the sample mean for the poor and non-poor populations. The number of repetitions was calibrated using Poi's *bssize* command in Stata.[3]

Possible endogeneity of total expenditures was a concern in estimation. To address this, in all stages of the estimation, an instrumental regression was used to obtain a predicted value of total expenditures. The instrumental regression used is given in equation 1.

$$E_h = \mu_0 + \mu_1(lnY_h) + \varepsilon_h \qquad (1)$$

Where E_h is total household expenditures, Y_h is the real income of household h μ_0 is the intercept, and ε_h is an error term. A description of the variables in this, and the following, regressions is in Table A.1.

In the first stage of the estimation, a Working–Leser (Working 1943; Leser 1963) model was used to estimate the price and expenditure elasticities of food versus nonfood consumption. The expenditure share of food, w_{if}, was estimated using equation 2.

$$w_{if} = \beta_1 \, log\left(\widehat{E_i}\right) + \beta_2 P_f + \sum \beta_3(Dem_i) + \sum \beta_4(District_i) + \varepsilon_{ij} \qquad (2)$$

Where $\log\left(\widehat{E_i}\right)$ is the log of the estimated total expenditure (on food and nonfood) from the instrumental regression, P_f is the average price of food, Dem_i is a vector of household level demographics which includes household size, age and sex of the head of household, square footage of the household, and the log of total household assets. $District_i$ is a set of district dummies for all 94 districts, and ε_{ij} is an error term. The conditional expenditure and Marshallian price elasticities were calculated using Leser's (1963) formulae shown in equations 3 and 4.

$$e_i = 1 + \frac{\beta_1}{w_{if}} \qquad (3)$$

$$e_{if} = -\delta_{ij} + \frac{\beta_2}{w_{if}} \qquad (4)$$

Where e_i is the expenditure elasticity, and e_{if} is the price elasticity. The Kronecker delta is represented by δ.

[3] The *bssize* command was calibrated to return standard errors that did not deviate by more than 5% from the ideal bootstrapped values with 99% probability.

Within the second and third stages, a modified QUAIDS model is estimated. The model (as well as the STATA code) was again adapted from Ecker and Qaim (2010). Adjustments were made to the standard QUAIDS model to account for censoring, explained below, and potential endogeneity, explained above. The same demographic control variables used in the Working–Leser model were also accounted for.

In the food consumption data there were a number of zero consumption observations, particularly among the observations for the separated four types of fish. To account for these, first a multivariate probit model was estimated for household consumption of the six categories of food, in the second stage, and the four categories of fish in the third stage. The probit model estimated using equation 5.

$$Pr(d_{ij} = 1|x_i) = \Phi(\theta_i x_i) \tag{5}$$

Where *i* and *j* index households and commodity subgroups respectively, d_{ij} indicates whether a household consumed a certain commodity (with $d_{ij} = 1$ if household *i* consumed good *j*), x_i is a combination of the same vector of household characteristics used before (Dem_i) and the log of the estimated total expenditure ($\log(\widehat{E_i})$), θ_i is a vector of parameters that translates x_i into the perceived changes in consumption, and Φ is the normal cumulative distribution function. From these probit models, the respective probability density and cumulative distribution functions were estimated and used to create the inverse mills ratio for each of the zero-observation commodities. These were then incorporated into the final QUAIDS models as demographic shifters to act as instruments correcting for zero observations.

With these adjustments, the final QUAIDS model is shown in equation 6.

$$w_{ij} = \alpha_i + \sum_{j=1}^{n} y_{ij} \, ln \, P_i + \beta_i ln \left[\frac{\widehat{m}}{a(p)}\right] + \frac{\lambda_j}{b(p)} \left\{ln \left[\frac{\widehat{m}}{a(p)}\right]\right\}^2 \tag{6}$$

Where w_{ij} is the consumption share of good *j* in household *i*, P_i is the price fced by the household, $\widehat{m}$ is the estimated household expenditure (as a result of the instrumental regression discussed previously) and $b(p)$ and $a(p)$ are the trans-log price aggregator functions.[4] Demographic shifters are incorporated into the

[4] Table A.2 in Annex III contains the descriptive statistics of all consumption shares and prices for the various food groups.

equation through the α's.

Finally, unconditional price elasticities were calculated using the estimates from all three stages. The expenditure elasticities are calculated relatively simply; by multiplying through the elasticities for all stages by good. The unconditional Marshallian were calculated using Edgerton's (1997) formula in equation 7.

$$e_{ij}^{u} = \delta_{rs} e_{(r)ij}^{c} + E_{(r)i} w_{(s)J}^{*} \left(e_{rs}^{c} + E_{r} w_{s}^{*} e_{f}^{u} \right) \tag{7}$$

Where i and j represent the subgroups at the third stage, r and s are the larger food subgroups in the second stage, and F represents the first stage of aggregate food. The Kronecker delta is calculated at the second stage and is again represented by δ.[5]

Demand Parameter Results

Table 3.1 presents the results of the demand parameter estimation, including estimated expenditure elasticities for all three years of the HIES used in this study. Consistent with the historical increase in aquaculture fish consumption, aquaculture expenditure elasticities increased for all household groups from 2000 to 2010. Inland capture, which saw much slower growth than aquaculture and increasing prices, showed mixed results across rural and urban households. Inland capture expenditure elasticities decreased in rural areas and increased in urban areas, with the biggest shift being a decrease for the rural poor. As this is the largest group in Bangladesh, the overall effect was a decrease in expenditure elasticities. Note that expenditure elasticities for the rural poor decreased for all types of fish except for aquaculture. For the other household groups, however, expenditure elasticities increased for most of the categories of fish.

[5] Alternative elasticity estimates were also calculated via an iterative linear least squares approach (utilizing Lecoq and Robin's *aidsills* command) and a QUAIDS model which did not account for censoring (using Poi's *quaids* command). Standard errors in the first of these alternative models are calculated from the command itself using the delta methodology, while standard errors for the second of these were calculated in the same method as our primary specification. Results can be found in Tables A.8 and A.9. Generally, the expenditure elasticity estimates produced by the alternate methods fell within the range of the model sensitivity testing described in Annex II. Those that did not, were nearly all larger in magnitude and in the marine fish category –the category with the most censoring. The alternative price elasticity estimates also mostly fell within the sensitivity testing range. All of those outside the range were on the higher end. Since neither of the alternative estimates account for censoring, it makes sense that the estimates produced by these methods are larger, as a household's zero-consumption observation is always treated as a direct response to increases in price or income. As such, we believe our primary estimation technique, and estimates, to be more valid.

Table 3.1: Expenditure elasticities by fish production system (QUAIDS model estimates)

	Rural poor	SE	Rural nonpoor	SE	Urban poor	SE	Urban nonpoor	SE
Primarily Aquaculture	0.99	(0.0001)	0.66	(0.002)	0.91	(0.0001)	0.57	(0.004)
Mixed	0.95	(0.0001)	0.64	(0.002)	1.16	(0.0001)	0.80	(0.006)
Primarily Inland Capture	1.04	(0.0001)	0.68	(0.002)	0.97	(0.0001)	0.68	(0.005)
Primarily Marine	0.98	(0.0001)	0.64	(0.002)	0.70	(0.0001)	0.32	(0.002)
2005 Expenditure Elasticities								
Primarily Aquaculture	1.29	(0.002)	1.07	(0.004)	1.44	(0.004)	1.15	(0.009)
Mixed	0.84	(0.001)	0.57	(0.002)	0.94	(0.003)	0.61	(0.005)
Primarily Inland Capture	0.91	(0.001)	0.67	(0.002)	1.02	(0.003)	0.72	(0.005)
Primarily Marine	1.23	(0.002)	1.11	(0.004)	1.38	(0.004)	1.19	(0.009
2010 Expenditure Elasticities								
Primarily Aquaculture	1.03	(0.001)	0.93	(0.002)	1.19	(0.001)	1.19	(0.003)
Mixed	0.83	(0.0001)	0.77	(0.001)	0.62	(0.001)	0.53	(0.001)
Primarily Inland Capture	0.72	(0.0001)	0.57	(0.001)	1.13	(0.001)	0.99	(0.003)
Primarily Marine	0.86	(0.001)	0.74	(0.001)	0.93	(0.001)	0.78	(0.002)

Source: Authors' calculations from HIES 2000, 2005, and 2010.

As shown in Table 3.2, estimates of the own–price elasticities of aquaculture decrease (meaning to become more negative) for all household groups from 2000 to 2010. Thus, demand for aquaculture fish has become less responsive to price changes over time. In contrast, Price responsiveness of most other fish has increased (become more elastic) over time. As we saw before, expenditure elasticities for aquaculture increased across all groups, so this move towards a more inelastic price response is surprising. Further data and analysis, disaggregated by type of fish, is needed.

Table 3.2: Econometric estimates of price elasticities of demand for fish

2000 Price Elasticities

		Rural								Urban							
		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE	Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-0.71**	(0.0001)	0.10	(0.0001)	-0.01	(0.0001)	-0.09	(0.0001)	**-0.69**	(0.0001)	0.11	(0.0001)	0.13	(0.0001)	0.03	(0.0001)
	Mixed	-0.10	(0.0001)	**-0.86**	(0.0001)	-0.06	(0.0001)	-0.19	(0.0001)	0.18	(0.0001)	**-0.83**	(0.0001)	0.19	(0.0001)	-0.02	(0.0001)
	Primarily Inland Capture	-0.06	(0.0001)	0.06	(0.0001)	**-0.91**	(0.0001)	-0.16	(0.0001)	0.09	(0.0001)	0.12	(0.0001)	**-0.81**	(0.0001)	0.08	(0.0001)
	Primarily Marine	0.04	(0.0001)	0.21	(0.0001)	0.12	(0.0001)	**-0.88**	(0.0001)	0.02	(0.0001)	0.01	(0.0001)	0.17	(0.0001)	**-0.69**	(0.0001)
Nonpoor	Primarily Aquaculture	**-0.81**	(0.0000)	0.01	(0.0001)	-0.07	(0.0001)	-0.14	(0.0001)	**-0.69**	(0.0001)	0.03	(0.0001)	0.02	(0.0001)	-0.02	(0.0001)
	Mixed	0.03	(0.0001)	**-0.88**	(0.0000)	-0.02	(0.0001)	-0.12	(0.0001)	0.34	(0.0001)	**-0.89**	(0.0001)	0.08	(0.0001)	0.02	(0.0001)
	Primarily Inland Capture	0.05	(0.0001)	0.07	(0.0001)	**-0.89**	(0.0000)	-0.06	(0.0001)	0.28	(0.0001)	0.13	(0.0001)	**-0.86**	(0.0001)	0.09	(0.0001)
	Primarily Marine	0.08	(0.0001)	0.13	(0.0001)	0.10	(0.0001)	**-0.88**	(0.0000)	-0.02	(0.0001)	0.05	(0.0001)	0.06	(0.0001)	**-0.66**	(0.0001)

2005 Price Elasticities

		Rural								Urban							
		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE	Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-0.83**	(0.0001)	0.10	(0.0001)	-0.05	(0.0001)	-0.16	(0.0001)	**-0.53**	(0.0001)	0.41	(0.0001)	0.25	(0.0001)	0.14	(0.0001)
	Mixed	0.02	(0.0001)	**-0.88**	(0.0001)	-0.14	(0.0001)	-0.13	(0.0001)	0.25	(0.0001)	**-0.66**	(0.0001)	0.09	(0.0001)	0.09	(0.0001)
	Primarily Inland Capture	0.24	(0.0001)	-0.04	(0.0001)	**-0.86**	(0.0001)	0.02	(0.0001)	0.39	(0.0001)	0.11	(0.0001)	**-0.71**	(0.0001)	0.17	(0.0001)
	Primarily Marine	-0.23	(0.0001)	0.38	(0.0001)	0.14	(0.0001)	**-0.91**	(0.0001)	-0.06	(0.0001)	0.54	(0.0001)	0.31	(0.0001)	**-0.75**	(0.0001)
Nonpoor	Primarily Aquaculture	**-0.92**	(0.0001)	0.01	(0.0001)	-0.14	(0.0001)	-0.21	(0.0001)	**-0.56**	(0.0001)	0.37	(0.0001)	0.22	(0.0001)	0.15	(0.0001)
	Inland Capture &Aquaculture	0.15	(0.0001)	**-0.94**	(0.0001)	-0.11	(0.0001)	-0.11	(0.0001)	0.29	(0.0001)	**-0.80**	(0.0001)	0.03	(0.0001)	0.03	(0.0001)
	Primarily Inland Capture	0.44	(0.0001)	-0.12	(0.0001)	**-0.92**	(0.0001)	0.05	(0.0001)	0.55	(0.0001)	-0.01	(0.0001)	**-0.81**	(0.0001)	0.16	(0.0001)
	Primarily Marine	-0.22	(0.0001)	0.44	(0.0001)	0.15	(0.0001)	**-0.92**	(0.0001)	-0.06	(0.0001)	0.60	(0.0001)	0.31	(0.0001)	**-0.77**	(0.0001)

2010 Price Elasticities

		Rural								Urban							
		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-0.81**	(0.0001)	-0.03	(0.0001)	-0.20	(0.0001)	-0.21	(0.0001)	**-0.92**	(0.0001)	0.09	(0.0001)	-0.27	(0.0001)	-0.18	(0.0001)
	Mixed	0.10	(0.0001)	**-0.79**	(0.0001)	-0.08	(0.0001)	-0.17	(0.0001)	0.11	(0.0001)	**-0.78**	(0.0001)	-0.14	(0.0001)	-0.09	(0.0001)
	Primarily Inland Capture	0.12	(0.0001)	0.14	(0.0001)	**-0.80**	(0.0001)	0.00	(0.0001)	0.15	(0.0001)	0.14	(0.0001)	**-0.83**	(0.0001)	0.17	(0.0001)
	Primarily Marine	0.25	(0.0001)	0.15	(0.0001)	0.04	(0.0001)	**-0.80**	(0.0001)	0.16	(0.0001)	0.06	(0.0001)	0.12	(0.0001)	**-0.80**	(0.0001)
Nonpoor	Primarily Aquaculture	**-0.87**	(0.0002)	-0.03	(0.0001)	-0.25	(0.0001)	-0.20	(0.0001)	**-0.98**	(0.0001)	0.06	(0.0001)	-0.25	(0.0001)	0.01	(0.0001)
	Mixed	0.20	(0.0001)	**-0.81**	(0.0002)	-0.08	(0.0001)	-0.14	(0.0001)	0.17	(0.0001)	**-0.76**	(0.0001)	-0.14	(0.0001)	-0.01	(0.0001)
	Primarily Inland Capture	0.15	(0.0001)	0.11	(0.0001)	**-0.85**	(0.0002)	0.05	(0.0001)	0.12	(0.0001)	0.02	(0.0001)	**-0.80**	(0.0001)	0.35	(0.0001)
	Primarily Marine	0.30	(0.0001)	0.05	(0.0001)	0.01	(0.0001)	**-0.81**	(0.0002)	0.04	(0.0001)	-0.07	(0.0001)	0.04	(0.0001)	**-0.82**	(0.0001)

Source: Authors' calculations from HIES 2000, 2005, and 2010.

Also surprising is that the cross–price elasticity between aquaculture and inland capture decreases by relatively large margins within each group, in some cases with changes in sign from positive to negative across the three surveys. This could indicate that the two are becoming stronger complements rather than substitutes, however, further detailed analysis of consumption by fish type is needed to untangle the reasons for these changes. Note also that the cross price of elasticities of demand of inland capture fish with respect to the price of aquaculture increase for nearly all household groups, with positive cross price elasticities of demand for all household groups in 2010 (indicating the two types of fish are substitutes). Again, further analysis is needed.[6]

[6] Appendix III contains alternative estimates of own price and cross price elasticities used to validate the parameters estimated for the model.

4. MODEL SIMULATIONS

Model Specification

In order to project future fish supply, demand and prices and to analyze the effects of various shocks, we use a simple partial equilibrium multimarket model.[7] We specify a set of demand and supply equations for the fish market in Bangladesh and input parameters across four types of fish and four household groups. As explained above, some of the demand parameters were estimated using the various HIES results in Bangladesh. The HIES was also used to calculated household incomes and consumption and population. The other exogenous variables and parameters derive from a variety of sources, including World Bank data (growth rates of population and GDP per capita) and BBS data (quantities of fish production and exports).[8] The full list of model variables and parameters is given in Table 4.1 below.

Table 4.1: Model variables and parameters

$QD_{h,c}$	Per Capita Quantity Demanded/Consumed
Y_h	Per Capita Household Income
ygr_h	Household Income Growth Rate
Pop_h	Population, by Household Group
$popgr_h$	Population Growth Rate
QS_c	Quantity Produced, by Fish Type
$qsgr_c$	Production Growth Rate
E	Exports
P_c	Fish Price
es_c	Elasticity of Supply
$edhh_{c,c,h}$	Household Price Elasticity
$edy_{c,h}$	Household Income Elasticity

Source: Authors.

The model consists of five sets of equations. Household income per capita is estimated as the base level of per capita income ($Y0_h$) multiplied by an exogenous rate of growth (1 +ygr_h (equation 8):

$$Y_h = Y0_h * (1 + ygr_h) \tag{8}$$

Quantity supplied (production) of each fish type i is calculated as the base level of quantity QS0 supplied, the (exogenous) productivity growth rate ($qsgr_i$) and current to base year prices (P_i / $P0_i$):

[7] Multimarket models are particularly useful for looking at sectoral level analysis rather than full economies and can allow for disaggregated policy impact evaluation (Braverman and Hammer 1986, Sadoulet and de Janvry 1995, Croppenstedt et al. 2007).
[8] A table documenting the historical trend of exports can be found in Table A.3 of Annex III.

$$QS_i = QS0_i * (1 + qsgr_i) * \frac{P_i}{P0_i}^{es_i} \tag{9}$$

where es_i is the elasticity of supply of fish type *i*.

Per capita household demand of each fish type *i* for household *h* is calculated as a function of the base level of demand, $QD0_{h,i}$, ratios of current to base year prices (P_i / $P0_i$) and the ratio of current to base year household income (Y_h / $Y0_h$):

$$QD_{h,i} = QD0_{h,i} * \prod \frac{P_i}{P0_i}^{ed_{h,i,j}} * \frac{Y_h}{Y0_h}^{edy_{h,i}} \tag{10}$$

where ed_{ij} is the elasticity of demand of fish type *i* with respect to the price of commodity *j*.

Aggregate demand is simply as the sum of per capita household demands multiplied by the population of the household group (the base year population multiplied by one plus the exogenous population growth rate), (Equation 11).

$$QD_i = \sum(QD_{h,i} * (Pop_h * (1 + popgr_h)) \tag{11}$$

Finally, Equation 12 defines the market equilibrium condition: total quantity demanded by domestic households is equal to supply minus exports.[9]

$$QD_i = QS_i - E_i \tag{12}$$

Simulation Results

In the base scenario, we set productivity growth for aquaculture and mixed production systems to an average of 3.7 and 1.5 percent per year, respectively – rates which are slightly lower than recent historical growth rates of production (Table 4.2). For inland capture and marine capture, we assume no productivity growth, given possible limits on sustainable increases in production.[10] Consistent with recent trends, urban population is projected to grow much faster than rural population (3.0 and 0.4 percent per year, respectively), with faster growth with overall incomes in urban areas, as well (Table 4.3). Overall, we model

[9] Exports in the model are assumed to be 20 percent of the baseline production for all categories. For the following years aquaculture exports are set at 50 percent of the previous year's production to reflect increased exports in this subcategory.
[10] These productivity shocks are chosen to produce trends in production and real prices similar to those observed from 2010 to 2015. Similar assumptions were used in World Bank (2007).

five policy scenarios with various combinations of productivity growth and increased demand (arising from exogenous increases in household incomes).

Table 4.2: Model simulation assumptions for fish productivity growth

	Aquaculture	Inland capture	Mixed	Marine
Average growth rate				
Base	3.7%	0.0%	1.5%	0.0%
High productivity	5.3%	0.8%	2.1%	0.0%
Very high productivity	6.7%	0.8%	2.1%	0.0%
Cumulative growth				
Base	71.5%	0.0%	25.0%	0.0%
High productivity	118.0%	12.7%	36.6%	0.0%
Very high productivity	163.1%	12.7%	36.6%	0.0%

Notes: Productivity growth rates for aquaculture in the base scenario are set equal to 5.0 percent for 2016 to 2020 and 3.0 percent for 2021 to 2030. For the high productivity scenarios, productivity growth rates for aquaculture are set equal to 5.0 and 3.0 percent for 2016–20 and 2021–30 periods. Similarly, for the very high productivity growth scenarios, aquaculture productivity growth is set equal to 8.0 and 6.0 percent in the two periods, respectively

Source: Authors.

Table 4.4 presents the simulation results in terms of annual growth rates of production and prices from 2015–2030. In the base simulation, total fish production from 2015 to 2030 increases by an average of 2.61 percent per year (47.2 percent in fifteen years), with very slow rates of growth for inland capture and marine fish production (1.56 and 1.37 percent per year, respectively), given the assumptions of zero productivity growth in these sectors. Production of inland capture fish in 2030 is projected to be only 26.1 percent higher than in 2015, and marine fish production is only 22.6 percent higher than in 2015. With increased demand as population and incomes rise, real prices of these types of fish increase over time, by 5.29 and 4.63 percent per year, respectively (with cumulative real price increases of 116.7 and 97.3 percent). By contrast, aquaculture and mixed system production increase relatively rapidly over time, by 3.65 and 1.76 percent per year, respectively, so that prices of aquaculture actually fall and mixed rise only slightly—by -0.2 and 0.84 percent per year (with cumulative price effects of -0.3 and 13.4 percent by 2030).[11] Fish consumption

[11] Earlier fish projections by World Bank (2007) for 2001 to 2015 assumed a growth rate of aquaculture of 10 percent per year, as compared to our calculated growth rate for this period of 8.6 percent and our base line growth rate of 3.65 percent for 2016 to 2030. Both analyses assume minimal growth of marine fish production. The two projections differ more substantially for inland capture, however. World Bank (2007) projects a growth rate of -7 percent for 2001 to 2015. Our calculations for the period show a positive (though somewhat low) growth rate of 0.8 percent, with a projected growth rate of 1.56 percent for 2016 to 2030 in the base simulation.

per capita rises by 27 percent, overall, between 2015 and 2030, with particularly large increases for urban households (Table 4.5).

Table 4.3: Model simulation assumptions for population and income growth

	Urban		Rural		Total
	Poor	Nonpoor	Poor	Nonpoor	
Base					
Population 2010 (millions)	20.50	18.75	52.50	57.50	149.25
Population growth	3.0%	3.0%	0.4%	0.4%	1.1%
Income growth	6.0%	4.0%	3.0%	2.0%	4.2%
Per capita income growth	2.9%	1.0%	2.6%	1.6%	3.1%
High demand					
Population growth	3.0%	3.0%	0.4%	0.4%	1.1%
Income growth	8.0%	6.0%	5.0%	4.0%	6.5%
Per capita income growth	4.9%	2.9%	4.6%	3.6%	5.4%

Source: Authors.

Table 4.4: Bangladesh fish production and prices: Simulation results

Annual growth rates: 2015–2030					
Production					
	Aquaculture	**Inland capture**	**Mixed**	**Marine**	**Total fish**
Base 2015 level	1654.8	467.5	1022.2	496.5	3641.0
Growth rates					
Base	3.65%	1.56%	1.76%	1.37%	2.61%
Sim 1	4.89%	2.07%	2.17%	1.32%	3.43%
Sim 2	4.17%	2.08%	2.19%	1.81%	3.10%
Sim 3	5.41%	2.59%	2.61%	1.75%	3.92%
Sim 4	5.82%	2.03%	2.14%	1.28%	3.94%
Sim 5	6.35%	2.55%	2.58%	1.72%	4.44%
Price					
	Aquaculture	**Inland capture**	**Mixed**	**Marine**	**Average fish**
Base 2015 level	103.99	127.61	109.01	220.20	140.2
Growth rates					
Base	-0.02%	5.29%	0.84%	4.63%	3.8%
Sim 1	-1.06%	4.26%	0.22%	4.45%	3.2%
Sim 2	1.24%	7.10%	2.30%	6.16%	5.3%
Sim 3	0.19%	6.06%	1.66%	5.97%	4.8%
Sim 4	-1.97%	4.12%	0.12%	4.34%	3.0%
Sim 5	-0.73%	5.91%	1.56%	5.84%	4.6%

Notes: Sim 1: High productivity, all systems.
Sim 2: Increased household fish demand.
Sim 3: Sim 1 with increased household demand.
Sim 4: Sim 1 with extra aquaculture productivity gains.
Sim 5: Sim 4 with increased household demand.
Source: Model simulations.

In Simulation 1, we model increased productivity and output of fish. In particular, we increase productivity of aquaculture by 5 percent per year for five years (2016 to 2020) and then slow the rate of productivity growth to 3 percent per year for the remaining ten years of the simulation (2021 to 2030). For inland capture and mixed systems, we assume constant annual increases in productivity increases of 0.8 and 2.1 per year over all fifteen years of the simulation. We assume no change in the productivity of marine fish (Table 4.2).

Under these assumptions, aquaculture production rises by 4.89 percent per year (120.5 percent over the 15-year period). Prices of aquaculture fish fall steeply, by 1.02 percent per year, (14.7 percent by 2030). With faster growth in inland capture fish (2.07 percent per year compared to 1.56 percent per year in the base simulation), prices rise by only 4.26 percent per year (86.9 percent by 2030), compared to an increase of 5.29 percent per year (116.7 percent by 2030) in the base simulation. Likewise, production of the mixed system rises by 2.17 percent per year (compared to 1.76 percent per year in the base simulation) and prices of mixed system fish only increase by 0.22 percent per year (3.3 percent by 2030). Total fish consumption per capita in 2030 is 56 percent higher than in 2015; 29 percent higher than in 2030 in the base simulation.

In Simulation 2, we model faster household income growth that results in increased demand for fish, along with higher prices relative to the base simulation. Increased demand leads to moderate increases in prices and a corresponding supply response. Overall, fish production increases by 3.10 percent per year, compared with 2.61 percent per year in the base simulation. By 2030, increased demand results in an overall gain of 58 percent in fish production relative to the base simulation.

The third simulation is a combination of the first two simulations (higher productivity growth along with increased fish demand). Overall, the effects of increased productivity and supply outweigh the impacts of increased demand. Overall fish production in 2030 is 17 percent higher than in the base simulation and only 5 percent lower than in the high productivity scenario with no demand increase (Simulation 1).

Simulation 4 models an additional increase in productivity growth and production of aquaculture, relative to the high productivity scenario (Simulation 1). As a result, aquaculture production increase by 5.82 percent per year, compared to 3.65 percent per year in the base simulation. Prices of aquaculture fall by 1.97 percent per year as compared to a decline of 0.02 percent per year in the base simulation, resulting in a decline of 26 percent and 0.3 percent, respectively, in 2030. Finally, Simulation 5 combines the higher income growth of simulation 2 with the accelerate productivity gains of Simulation 4. Again, increased demand results in a smaller price decrease in aquaculture, (only 0.73 percent per year, as compared to 1.97 percent per year in Simulation 4).

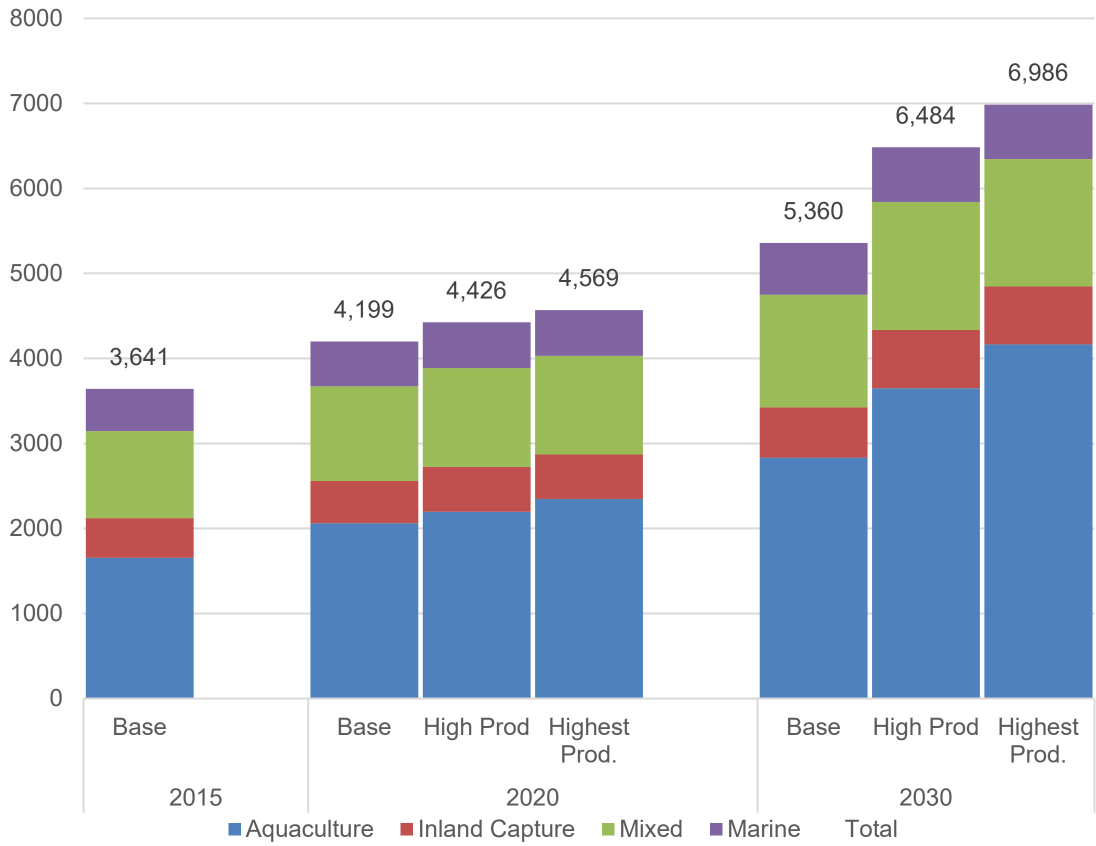
Table 4.5: Bangladesh fish consumption: Simulation results

		Aquaculture	Inland capture	Mixed	Marine	All fish
	Per capita consumption					
Base 2015	**Level (kg per capita)**					
	Rural nonpoor	12.09	2.29	5.72	1.72	21.81
	Rural poor	7.46	1.88	4.33	0.89	14.56
	Urban nonpoor	13.72	3.78	6.88	5.78	30.15
	Urban poor	11.23	3.03	5.94	2.75	22.96
	All Bangladesh	10.49	2.46	5.41	2.16	20.53
	Percent change 2015–2030					
Base	Rural nonpoor	-5.1%	-35.4%	-2.4%	-26.8%	-9%
	Rural poor	16.7%	-24.3%	9.5%	-10.7%	8%
	Urban nonpoor	69.1%	22.8%	10.4%	-7.3%	35%
	Urban poor	105.5%	61.7%	31.4%	44.1%	73%
	Total	42.2%	9.1%	12.7%	10.3%	27%
Sim 3	Rural nonpoor	47.2%	-15.8%	34.3%	-1.9%	33%
	Rural poor	65.8%	-3.3%	37.1%	14.6%	45%
	Urban nonpoor	125.9%	60.5%	15.6%	-1.0%	68%
	Urban poor	89.2%	55.8%	16.1%	26.9%	58%
	Total	83.0%	29.8%	29.8%	19.0%	56%
Sim 5	Rural nonpoor	67.7%	-16.4%	32.7%	-4.6%	44%
	Rural poor	87.1%	-3.5%	37.4%	12.0%	56%
	Urban nonpoor	159.9%	59.3%	14.6%	-0.1%	83%
	Urban poor	116.8%	54.4%	16.2%	25.4%	72%
	Total	108.9%	28.9%	29.2%	18.1%	69%

Notes: Sim 1: High productivity, all systems.
Sim 2: Increased household fish demand.
Sim 3: Sim 1 with increased household demand.
Sim 4: Sim 1 with extra aquaculture productivity gains.
Sim 5: Sim 4 with increased household demand.
Source: Model simulations.

Figure 4.1 below summarizes the results of base scenario, high productivity / high demand scenario (simulation 3) and the high productivity aquaculture / high demand scenario (simulation 5). As indicated, total fish production is projected to grow rapidly if aquaculture investment and productivity continue to increase, potentially reaching 6.48 million tons in 2030 in simulation 3 and 6.99 million tons in simulation 5, (20.9 and 30.3 percent increases relative to the base line figure).

Figure 4.1: Simulation results: Bangladesh fish production (thousand tons)



Source: Model simulations.

Annex III presents sensitivity analysis using an alternative set of (more inelastic) demand parameters equal to 0.6 times those used in the main simulations (these results cane be seen in Tables A.11 and A.12 and Figure A.2). As expected, more inelastic demand implies larger price declines due to production increases (for example, Simulation 1a), but greater rises in the simulations involving exogenous increases in household incomes (for example, Simulation 2a). Aquaculture fish prices fall by 1.34 percent per year in Simulation 3a and 2.62 percent per year in Simulation 5a, compared with small yearly increases of 0.19 and decline of 0.73 percent per year in the corresponding simulations using the base parameters. More inelastic demand and resulting larger price declines also dampen production increases, so that overall fish production rises by only 3.41 and 3.81 percent per year in Simulations 3a and 5a.

5. CONCLUSIONS

Fish production, particularly production from aquaculture, has increased rapidly in Bangladesh in the last decade. As a result, in spite of rising household incomes and consumer demand, real prices of fish produced from aquaculture systems have fallen. Moreover, prospects for future growth of household incomes are good, given public, private, and foreign investment in infrastructure. Improved infrastructure and changes in information and telecommunication and technology could also further raise productivity and household incomes. Thus, household demand for fish products will likely increase substantially if per capita incomes continue to rise as expected.

Our analysis of potential increases in fish production (most of which would likely come from aquaculture) suggests that if present rates of investment in aquaculture and productivity growth continue, fish production growth is likely to outpace these increases in demand. In our base (moderate productivity growth) scenario, aquaculture and total fish production increase by an average of 3.65 and 2.61 percent per year from 2015 through 2030, contributing to a decline in real prices of aquaculture by -0.02 percent per year through 2030. Increases in aquaculture investment and productivity could lead to greater overall increase in production of as much as 120 percent in 2030 relative to 2015. If demand also increases rapidly, real aquaculture prices may fall by only 0.73 percent through 2030. Even greater aquaculture investments and larger productivity gains (by another 2 percent) could raise production to 6,986 million tons by 2030, 152 percent greater than in 2015 and a 69 percent increase in per capita consumption. Poor households who currently consume only small quantities of fish (14.56 kg/capita in 2015 for the rural poor as compared to 30.15 kg/capita for the urban nonpoor) stand to gain significantly from these greater production and lower prices, with potential increases of 6.5 and 20.5 kg/capita, respectively, provided that improvements in storage, transport, and basic processing can make increase their access to these increased supplies.

These trends also imply significant changes in relative prices of various types of fish. Investments in aquaculture have the potential to lead to significant increases in production, and possibly reduce real prices of aquaculture fish. In contrast, ecosystem constraints on sustainable fish production in inland capture and marine fishing are likely to limit production gains in these systems. All the model simulations indicate major shifts in consumption patterns and relative prices arising from these significant differences in production potential.

Thus, inadequate demand is unlikely to be a major constraint on the Bangladesh fish sector, particularly for aquaculture. Although other production systems (inland capture and marine fishing) face serious constraints and are unlikely to increase their output significantly over time, the simulations suggest that sustained increases in aquaculture production at rates approximating those of recent years would be sufficient to meet rising fish demand in Bangladesh. Moreover, increased supply could lead to moderate declines in the real price of fish products and enable poor Bangladeshi households to increase their consumption of this nutrient–rich food.

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ANNEX I: ALTERNATE DEMAND ELASTICITY ESTIMATES

Given the importance of the household demand parameters for the model results, we present alternative estimates of these parameters based on econometric estimates using a Linear Expenditure System specification (see Dervis, de Melo, and Robinson 1982).

We first estimate expenditure elasticities from simple Engel functions using a Heckman two-step methodology (Heckman 1979, Leser 1963). Following this methodology, to correct for the possibility of zero consumption for each fish type by running a multivariate probit model shown below.

$$d_{ij} = \beta_1 \, log(E_{ij}) + \sum \beta_2 (Dem_i) + e_{ij}$$

Where *i* and *j* index households and commodity subgroups respectively, d_{ij} indicates whether a household consumed a certain commodity (with $d_{ij} = 1$ if household *i* consumed good *j*), E_{ij} is household i's expenditure on good j, and Dem_i is a vector of household level demographics which includes household size, age and sex of the head of household, square footage of the household, and district. From these probit models, the respective probability density and cumulative distribution functions were estimated and used to create the inverse mills ratio for each of the zero-observation commodities.

We then correct for endogeneity of household expenditures using an instrumental regression to obtain a predicted value of total expenditures. The instrumental regression used was:

$$TE_{ij} = \beta_1 (lnY_i) + e_{ij}$$

Where TE_h and Y_h are the total expenditure and real incomes of household h.

Next, the instrumented total expenditures and inverse mills ratio were used in the following regression:

$$w_{hfood} = \beta_1 \, ln(\widehat{TE}_h) + \beta_2 * ln(\widehat{TE}_h)^2 + ln\beta_3 P_{food} + \sum \beta_4 (Dem_i) + \sum \beta_5 (District_i) + \lambda_i + e_{ij}$$

Where $log(\widehat{TE}_h)$ is the log of the estimated total expenditure (on food and nonfood) from the instrumental regression, lnP_{food} is the natural log of the average price of food, Dem_i is the vector of household level (now excluding the district variable), $District_i$ is a set of district dummies for all 94 districts, and λ_i is the inverse mills ratio.

Finally, expenditure elasticities are calculated from these Engel functions using the following equation:

$$e_i = 1 + \frac{\beta_1}{w_i}$$

Where e_i is the expenditure elasticity. And then own–price and cross–price elasticities are calculated using the LES equations as such:

$$e_{ii} = -e_i\,(\frac{AvgP_i * TE_i}{w_i} - \frac{1}{\phi})$$

$$e_{ij} = -e_i(\frac{P_j * TE_j}{w_i})$$

Where e_{ii} is the own–price elasticity, e_{ij} is the cross–price elasticity, and ϕ is the Frisch parameter (Dervis, de Melo, and Robinson 1982).

The resulting elasticities are presented in Table A.6 and A.7

We have done this exercise across the four fish categories used in the main analysis, but we have also done it between fresh water and marine fish categories for further exploration. The fresh water category was calculated by simply combining the three categories that are not marine.

Comparing these results to the ones used in the model, we can see similarities in the direction of the signs and in the general magnitudes. For example, the own price elasticities are all mostly negative and less than 1. Note that the magnitude of the cross–price elasticities are smaller than those estimated using the QUAIDS model (Table 3.2). The small magnitudes of the cross–price elasticities may be due to aggregating various types of fish by production system rather than by characteristics reflecting consumer preferences. Further work on fish demand by fish type could shed light on these issues.

ANNEX II: MODEL CALIBRATION AND VALIDATION

After the model was constructed, calibration was employed to match the simulation productivity and price growth rates with the historical price and growth trends. Calibration targets were calculated using available BBS data on price and production for different fish types. The exogenous parameter we used in calibration was supply elasticity. Table A.10 shows the final results of the calibration, with the most reasonable price and production errors we arrived at given plausible supply elasticities.

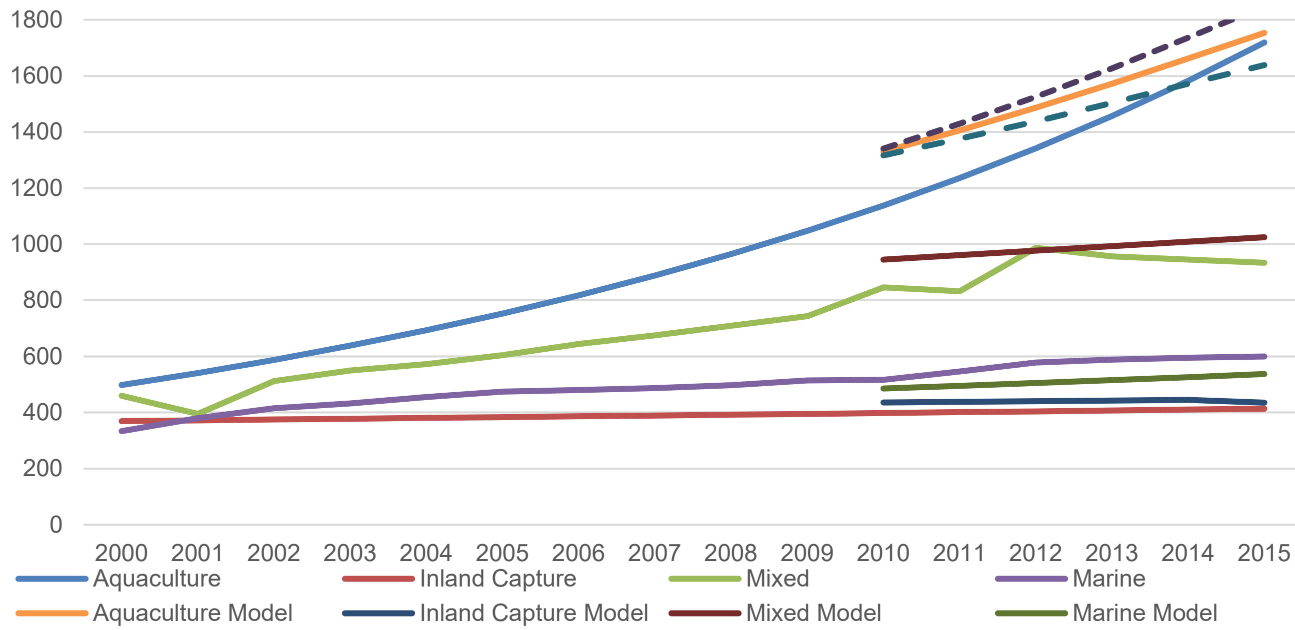
The highest overall error rates are that for price in aquaculture and production in mixed. It is interesting that we see a too high of a price decrease in our model even though we also see too low of a production rate increase. More could be done to investigate this dichotomy.

Validation was also undertaken to investigate how well the trends from the model matched the historical trends from the BBS data. Figure 6.A1 below has the results of this. We graphed the BBS data from 2000 to 2015 and then overplayed the graphs of our model results from 2010 to 2015. The model matched the results relatively well. Though the initial levels differ due to the model being based on the HIES data and the historical trends being from the BBS, the slopes tend to match well.

For aquaculture, we provide to additional trend lines. The solid line represents production results using the demand parameters estimated from the QUAIDS model. The lines above and below this represent the results when we double the price elasticities for aquaculture and halve them, respectively. Both of these have a visible effect on the trend line, with halving the elasticities causing a more dramatic shift in production. In the end, we decided on the original parameters for the final estimates.

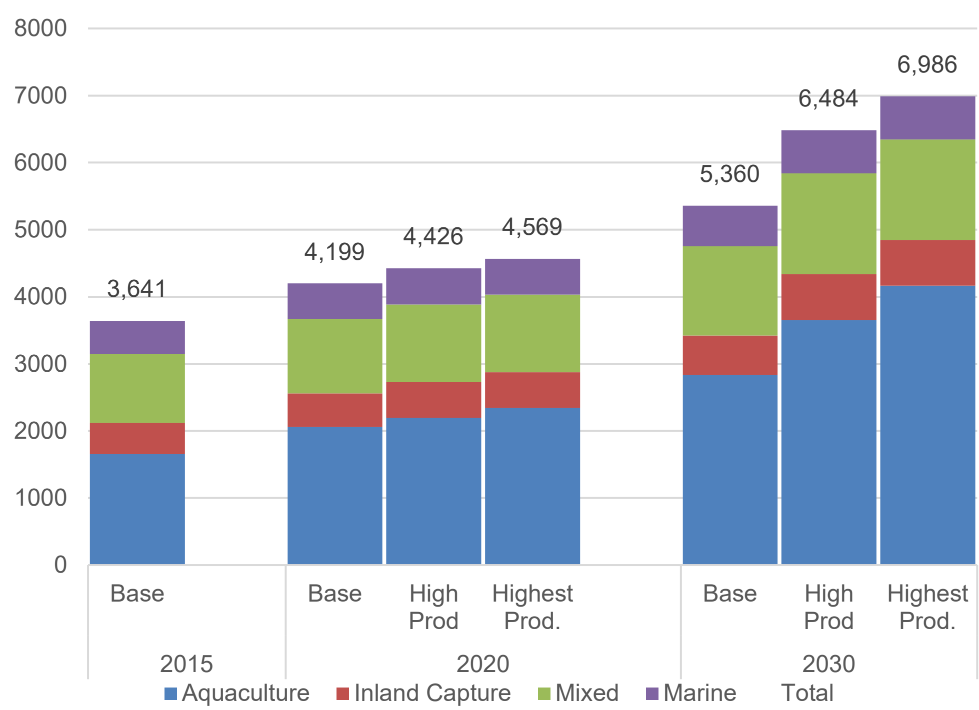
ANNEX III: ANNEX FIGURES AND TABLES

Figure A.1: Model validation: Production by fish system (thousand tons)



Source: Model simulations.

Figure A.2: Simulation results: Bangladesh fish production (alternative parameters), (thousand tons)



Source: Model simulations.

Table A.1: Demographic variables used in the econometric estimation of household demand parameters

		2000				2005				2010			
Variable	**Description**	**Mean**	**Std. dev.**	**Min**	**Max**	**Mean**	**Std. dev.**	**Min**	**Max**	**Mean**	**Std. dev.**	**Min**	**Max**
log real income	Natural log of real income	11.40	0.90	4.94	15.68	10.97	0.88	5.99	16.25	10.84	0.81	5.39	16.38
sqft	Square footage of residence	402	420	0	20000	391	308	30	4207	368	1435	0	120000
hhsize	Continuous household size	4.5	1.9	1.0	17.0	4.9	2.1	1.0	20.0	5.2	2.2	1.0	25.0
sex	Binary variable denoting sex of head of household	0.86	0.35	0.00	1.00	0.90	0.30	0.00	1.00	0.09	0.29	0.00	1.00
lnage	Natural log of age of head of household	3.78	0.30	2.40	4.80	3.77	0.30	2.48	4.60	3.75	0.30	2.48	4.60
tasset	Total household assets, in thousands	43	280	-2240	13100	18	85	-2800	4094	25	257	-45	16300

Source: Authors' calculations from HIES 2000, 2005, and 2010.

Table A.2: Share and price variables: Descriptive statistics

		2000				2005				2010			
Variable	Description	Mean	Std. dev.	Min	Max	Mean	Std. dev.	Min	Max	Mean	Std. dev.	Min	Max
w1	Consumption share of primarily aquaculture	3%	4%	0%	38%	4%	4%	0%	30%	5%	5%	0%	36%
w2	Consumption share of mixed	4%	4%	0%	48%	4%	4%	0%	40%	4%	4%	0%	42%
w3	Consumption share of primarily inland capture	4%	4%	0%	30%	3%	3%	0%	32%	2%	3%	0%	34%
w4	Consumption share of primarily marine	2%	4%	0%	39%	2%	4%	0%	39%	3%	4%	0%	53%
w5	Consumption share of food grains and pulses	45%	15%	0%	87%	44%	15%	0%	100%	40%	15%	0%	86%
w6	Consumption share of dairy, eggs, and meat	6%	5%	0%	52%	6%	4%	0%	39%	7%	5%	0%	48%
w7	Consumption share of vegetables and fruit	11%	10%	0%	64%	11%	10%	0%	62%	12%	11%	0%	80%
w8	Consumption share of oils, fats, and sugars	14%	5%	0%	44%	13%	5%	0%	48%	13%	5%	0%	61%
w9	Consumption share of misc.	12%	7%	0%	100%	13%	8%	0%	100%	13%	7%	0%	100%
p1	Price of primarily aquaculture	55.9	19.9	6.6	300.0	58.1	16.6	8.0	200.0	103.4	25.1	40.0	300.0
p2	Price of mixed	47.7	19.0	10.0	400.0	56.3	20.9	12.0	200.0	109.9	33.0	40.0	500.0
p3	Price of primarily inland capture	48.3	20.3	7.1	328.0	62.5	22.7	4.0	750.0	126.8	42.9	48.0	800.0
p4	Price of primarily marine	80.9	41.0	10.9	2000.0	103.1	34.2	10.0	800.0	220.4	84.8	40.0	1000.0
p5	Price of food grains and pulses	12.5	1.8	5.5	36.0	17.4	1.9	3.6	29.0	33.3	4.5	20.4	76.0
p6	Price of dairy, eggs, and meat	26.9	10.0	2.4	103.6	38.0	11.9	2.5	512.5	66.9	27.6	11.1	283.1
p7	Price of vegetables and fruit	448.0	913.7	9.0	4000.0	537.9	1066.1	11.8	5000.0	1084.8	2091.5	14.0	8000.0
p8	Price of oils, fats, and sugars	8.6	3.0	2.5	38.5	9.7	3.7	3.0	81.1	18.0	7.9	4.2	88.7
p9	Price of misc.	86.6	78.6	7.9	5457.5	87.0	40.0	18.3	500.0	132.3	66.2	32.8	1108.8

Note: Prices are directly from HIES and have not been adjusted for inflation.

Source: Authors' calculations from HIES 2000, 2005, and 2010.

Table A.3: Bangladesh fish exports, 2000–2014 (thousand tons)

Year	Frozen shrimp	Frozen fish	Dry fish	Salted fish	Turtles /crab	Shark fish+others	Total
2000	28.51	9.48	0.22	0.81	0.11	0.26	39.39
2001	29.71	7.97	0.14	0.84	0.15	0.18	38.99
2002	30.21	9.86	0.52	0.29	0.34	0.26	41.48
2003	36.86	8.85	0.33	0.53	0.63	0.17	47.37
2004	42.94	10.23	0.47	0.38	0.12	0.18	54.14
2005	46.53	15.76	0.27	0.77	0.04	0.17	63.38
2006	49.32	17.43	0.15	0.59	1.11	0.08	68.83
2007	53.36	18.38	0.08	0.44	1.12	0.24	73.70
2008	49.91	23.52	0.21	0.66	0.44	0.27	75.30
2009	50.37	19.29	0.34	0.08	1.22	0.28	72.89
2010	51.60	21.46	0.62	0.19	0.69	0.96	77.64
2011	54.89	16.74	0.62	0.58	4.49	1.78	96.47
2012	48.01	15.51	1.00	0.41	5.77	1.76	92.48
2013	50.33	11.44	1.28	0.54	7.43	1.60	84.91
2014	47.64	11.68	2.63	0.26	7.71	2.39	77.33

Note: To compute production values for use in the model, processing loss was assumed to be 50 percent (Portley 2016). As such, the exports in the model were doubled what is presented in the table.

Table A.4: Breakdown of fish categories

Major group	Fish name
Primarily aquaculture	Rhui/ Katla/ Mrigel/ Kal baush
	Silver carp/ Grass carp/ Miror carp
	Pangash/ Boal/ Air
Mixed	Kai/ Magur/ Shinghi/ Khalisha
	Koi
	Mala–kachi/ Chala–chapila
	Puti/ Big Puti/ Telapia/ Nilotica
Primarily inland capture	Shoal/ Gajar/ Taki
	Tangra/ Eelfish
	Baila/ Tapashi
	Shrimp
	Other
Primarily marine	Hilsa
	Dried fish
	Sea fish

Source: Toufique and Belton, 2014.

Table A.5: Scientific names for all fish by category

Category	Fish Name	Scientific Names
Aquaculture	Rhui	*Labeo rohita*
	Katla	*Catla catla*
	Mrigel	*Cirrhinus cirrhosus*
	Kal baush	*Cyprinus calbasu*
	Silver carp	*Hypophthalmichthys molitrix*
	Grass carp	*Ctenopharyngodon idella*
	Mirror carp	*Cyprinus carpio carpio*
	Pangash	*Pangasius pangasius*
	Boal	*Wallago attu*
	Air	*Bagarius bagarius*
Mixed	Kai	*Xenentodon cancila*
	Magur	*Clarias batrachus*
	Shinghi	*Heteropneustes fossilis*
	Khalisha	*Tirchogaster chuna*
	Koi	*Anabas testudineus*
	Mala–kachi	*Corica soborna*
	Chala–chapila	*Gudusia chapra*
	Puti	*Puntius sophore*
	Big puti	*Barbonymus gonionotus*
	Telapia	*Oreochromis mossambicus*
	Nilotica	*Oreochromis niloticus niloticus*
Inland capture	Shoal	*Channa striata*
	Gajar	*Channa marulius*
	Taki	*Channa punctata*
	Tangra	*Devario anomalus*
	Eelfish	*Gong magor*
	Balia	*Glossogobius giuris*
	Tapashi	*Polynemus paradiseus Linnaeus*
	Shrimp	*Macrobrachium rosenbergii*
Marine	Hilsa	*Tenualosa ilisha*

Source: Wikipedia 2018 and Fishbase 208.

Table A.6: Own–price elasticity estimates using LES

Category	Own Price Elasticity			
	Rural poor	Rural nonpoor	Urban poor	Urban nonpoor
Primarily aquaculture	-0.24	-0.42	-0.52	-0.08
Inland cap & culture	-0.22	0.14	-0.38	-0.73
Primarily inland capture	-0.06	-0.53	-0.03	-0.04
Primarily marine	0.08	-0.18	0.21	-1.60
Fresh water	-0.29	-0.26	-0.22	-0.26
Marine	0.08	-0.18	0.21	-1.60

Source: Authors' calculations from Bangladesh HIES 2000,2005, and 2010.

Table A.7: Cross–price elasticity estimates using LES

	Wealth group	Cross price elasticities			
		Primarily aquaculture	Mixed	Primarily inland capture	Primarily marine
Primarily aquaculture	Rural poor	-	-0.0023	-0.0013	-0.0021
	Rural nonpoor	-	-0.0039	-0.0022	-0.0048
	Urban poor	-	-0.0076	-0.0045	-0.0105
	Urban nonpoor	-	-0.0011	-0.0007	-0.0025
Mixed	Rural poor	-0.0024	-	-0.0012	-0.0019
	Rural nonpoor	0.0018	-	0.0007	0.0015
	Urban poor	-0.0053	-	-0.0033	-0.0076
	Urban nonpoor	-0.0106	-	-0.0069	-0.0240
Primarily inland capture	Rural poor	-0.0006	-0.0005	-	-0.0005
	Rural nonpoor	-0.0069	-0.0049	-	-0.0060
	Urban poor	-0.0004	-0.0004	-	-0.0006
	Urban nonpoor	-0.0006	-0.0005	-	-0.0013
Primarily marine	Rural poor	0.0009	0.0008	0.0004	-
	Rural nonpoor	-0.0023	-0.0017	-0.0009	-
	Urban poor	0.0029	0.0030	0.0018	-
	Urban nonpoor	-0.0229	-0.0218	-0.0148	-
		Fresh Water	**Marine**		
Fresh water	Rural poor	-	-0.0025		
	Rural nonpoor	-	-0.0030		
	Urban poor	-	-0.0044		
	Urban nonpoor	-	-0.0083		
Marine	Rural poor	0.0020	-		
	Rural nonpoor	-0.0049	-		
	Urban poor	0.0076	-		
	Urban nonpoor	-0.0605	-		

Source: Authors' calculations from Bangladesh HIES 2000, 2005, and 2010.

Table A.8: Alternative specifications of expenditure elasticity parameters

	Rural Poor	SE	Rural nonpoor	SE	Urban Poor	SE	Urban nonpoor	SE
Iterated linear least-squares approach								
2000 Expenditure Elasticities								
Primarily Aquaculture	1.46	(0.109)	1.46	(0.080)	1.76	(0.296)	1.47	(0.187)
Mixed	0.87	(0.059)	0.81	(0.072)	0.74	(0.198)	0.76	(0.244)
Primarily Inland Capture	0.79	0.068)	0.06	(0.081)	0.45	(0.160)	0.29	(0.284)
Primarily Marine	0.97	(0.143)	1.23	(0.098)	1.00	(0.261)	1.16	(0.219)
2005 Expenditure Elasticities								
Primarily Aquaculture	1.18	(0.055)	1.10	(0.043)	1.20	(0.074)	1.12	(0.063)
Mixed	0.97	(0.045)	0.94	(0.052)	0.79	(0.067)	0.62	(0.088)
Primarily Inland Capture	0.83	(0.064)	0.71	(0.079)	0.85	(0.097)	0.87	(0.104)
Primarily Marine	0.89	(0.105)	1.27	(0.099)	1.19	(0.133)	1.45	(0.105)
2010 Expenditure Elasticities								
Primarily Aquaculture	1.07	(0.048)	1.02	(0.044)	1.07	(0.063)	0.99	(0.068)
Mixed	0.89	(0.048)	0.83	(0.056)	0.87	(0.060)	0.77	(0.075)
Primarily Inland Capture	0.94	(0.077)	0.90	(0.086)	1.15	(0.108)	0.99	(0.100)
Primarily Marine	1.13	(0.112)	1.37	(0.078)	0.96	(0.125)	1.31	(0.084)
Alternative QUAIDS approach								
2000 Expenditure Elasticities								
Primarily Aquaculture	1.32	(0.031)	1.49	(0.039)	1.05	(0.056)	-0.45	(1.005)
Mixed	0.67	(0.029)	0.50	(0.033)	1.06	(0.04)	2.34	(0.68)
Primarily Inland Capture	0.62	(0.065)	0.57	(0.039)	0.51	(0.11)	-3.83	(3.661)
Primarily Marine	1.23	(0.025)	1.40	(0.039)	1.46	(0.15)	2.01	(0.412)
2005 Expenditure Elasticities								
Primarily Aquaculture	1.20	(0.008)	1.15	(0.005)	1.00	(0.003)	0.98	(0.002)
Mixed	0.79	(0.02)	0.70	(0.016)	0.70	(0.03)	0.54	(0.034)
Primarily Inland Capture	0.91	(0.005)	0.94	(0.003)	1.04	(0.011)	1.10	(0.012)
Primarily Marine	1.26	(0.031)	1.35	(0.025)	1.53	(0.048)	1.52	(0.036)
2010 Expenditure Elasticities								
Primarily Aquaculture	0.91	(0.007)	0.84	(0.008)	0.58	(0.023)	0.29	(0.034)
Mixed	0.74	(0.019)	0.60	(0.019)	0.55	(0.033)	0.41	(0.03)
Primarily Inland Capture	0.99	(0.003)	0.98	(0.004)	1.03	(0.01)	0.91	(0.009)
Primarily Marine	1.72	(0.048)	2.19	(0.086)	2.73	(0.134)	2.89	(0.166)

Source: Authors' calculations from HIES 2000, 2005, and 2010.

Table A.9: Alternative specifications of price elasticity parameters

Iterated linear least-squares approach

2000 Price Elasticities

		Rural								**Urban**							
		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE	Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-2.25**	(0.149)	-0.31	(0.118)	-0.20	(0.106)	0.28	(0.084)	**-2.26**	(0.367)	-0.07	(0.273)	-0.37	(0.307)	0.78	(0.227)
	Mixed	0.02	(0.078)	**-0.95**	(0.071)	-0.24	(0.065)	0.20	(0.051)	0.13	(0.259)	**-0.76**	(0.232)	0.09	(0.248)	0.10	(0.169)
	Primarily Inland Capture	0.55	(0.090)	0.25	(0.084)	**-0.59**	(0.076)	-0.21	(0.061)	0.29	(0.217)	0.07	(0.192)	**-0.47**	(0.201)	-0.07	(0.14)
	Primarily Marine	1.24	(0.193)	-0.16	(0.179)	0.13	(0.161)	**-1.69**	(0.141)	1.32	(0.326)	-0.27	(0.292)	-0.36	(0.325)	**-2.19**	(0.236)
Non Poor	Primarily Aquaculture	**-2.03**	(0.104)	-0.28	(0.1)	-0.23	(0.091)	0.23	(0.072)	**-1.93**	(0.244)	-0.03	(0.22)	-0.27	(0.236)	0.60	(0.165)
	Mixed	0.01	(0.09)	**-0.93**	(0.084)	-0.25	(0.076)	0.24	(0.06)	0.12	(0.293)	**-0.74**	(0.265)	0.09	(0.288)	0.12	(0.109)
	Primarily Inland Capture	0.55	(0.101)	0.31	(0.091)	**-0.42**	(0.087)	-0.22	(0.065)	0.33	(0.293)	0.09	(0.258)	**-0.28**	(0.299)	-0.07	(0.187)
	Primarily Marine	1.01	(0.162)	-0.19	(0.137)	-0.11	(0.126)	**-1.55**	(0.098)	1.07	(0.308)	-0.28	(0.251)	-0.38	(0.266)	**-2.02**	(0.203)

2005 Price Elasticities

		Rural								**Urban**							
		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE	Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-1.71**	(0.078)	-0.26	(0.06)	0.02	(0.052)	0.12	0.04	**-1.55**	(0.081)	-0.24	(0.065)	0.04	(0.057)	0.45	(0.045)
	Mixed	0.00	(0.063)	**-1.09**	(0.05)	-0.14	(0.044)	0.31	0.04	0.23	(0.073)	**-1.06**	(0.06)	-0.03	(0.054)	0.25	(0.042)
	Primarily Inland Capture	0.75	(0.09)	0.34	(0.073)	**-1.02**	(0.064)	-0.37	0.05	0.41	(0.102)	0.16	(0.086)	**-1.22**	(0.077)	-0.33	(0.058)
	Primarily Marine	0.64	(0.146)	0.38	(0.119)	0.42	(0.105)	**-1.61**	0.09	0.24	(0.137)	0.47	(0.115)	0.28	(0.102)	**-2.13**	(0.088)
Non Poor	Primarily Aquaculture	**-1.57**	(0.06)	-0.19	(0.047)	0.04	(0.043)	0.10	0.04	**-1.47**	(0.067)	-0.19	(0.056)	0.05	(0.05)	0.40	(0.038)
	Inland Capture &Aquaculture	0.00	(0.073)	**-1.10**	(0.057)	-0.15	(0.051)	0.36	0.04	0.33	(0.091)	**-1.01**	(0.077)	-0.01	(0.066)	0.31	(0.05)
	Primarily Inland Capture	0.89	(0.115)	0.42	(0.085)	**-0.98**	(0.075)	-0.43	0.06	0.43	(0.114)	0.16	(0.092)	**-1.23**	(0.081)	-0.36	(0.064)
	Primarily Marine	0.57	(0.155)	0.24	(0.117)	0.23	(0.103)	**-1.61**	0.08	0.10	(0.121)	0.26	(0.1)	0.18	(0.087)	**-1.95**	(0.075)

2010 Price Elasticities

		Rural								Urban							
		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-1.69**	(0.079)	-0.15	(0.057)	0.24	(0.048)	0.25	0.03	**-1.17**	(0.08)	-0.31	(0.073)	-0.05	(0.054)	0.10	(0.038)
	Mixed	0.20	(0.076)	**-0.97**	(0.058)	-0.13	(0.05)	0.11	0.04	-0.12	(0.079)	**-0.80**	(0.067)	0.04	(0.053)	0.13	(0.037)
	Primarily Inland Capture	0.61	(0.118)	0.28	(0.092)	**-1.79**	(0.083)	-0.39	0.06	-0.14	(0.135)	0.02	(0.118)	**-1.50**	(0.092)	-0.23	(0.064)
	Primarily Marine	0.92	(0.164)	0.01	(0.131)	0.71	(0.115)	**-1.60**	0.09	0.77	(0.157)	0.29	(0.141)	0.51	(0.11)	**-1.27**	(0.081)
Non Poor	Primarily Aquaculture	**-1.64**	(0.069)	-0.13	(0.054)	0.23	(0.046)	0.25	0.03	**-1.15**	(0.085)	-0.29	(0.074)	-0.04	(0.057)	0.11	(0.041)
	Mixed	0.24	(0.087)	**-0.94**	(0.066)	-0.14	(0.056)	0.13	0.04	-0.12	(0.089)	**-0.74**	(0.083)	0.06	(0.062)	0.16	(0.044)
	Primarily Inland Capture	0.68	(0.142)	0.32	(0.105)	**-1.86**	(0.091)	-0.43	0.06	-0.08	(0.125)	0.09	(0.113)	**-1.46**	(0.086)	-0.21	(0.061)
	Primarily Marine	0.62	(0.141)	-0.10	(0.101)	0.50	(0.088)	**-1.49**	0.06	0.43	(0.117)	0.06	(0.101)	0.30	(0.077)	**-1.22**	(0.053)

Alternative QUAIDS approach

2000 Price Elasticities

		Rural								Urban							
		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE	Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-1.84**	(0.063)	-0.10	(0.03)	0.03	(0.027)	0.58	(0.044)	**-2.37**	(0.233)	-0.07	(0.014)	-0.05	(0.012)	1.43	(0.254)
	Mixed	0.10	(0.045)	**-0.89**	(0.031)	-0.10	(0.023)	0.22	(0.019)	-0.08	(0.017)	**-0.78**	(0.049)	-0.23	(0.041)	0.02	(0.014)
	Primarily Inland Capture	0.48	(0.14)	-0.33	(0.076)	**-0.10**	(0.072)	-0.68	(0.048)	0.14	(0.031)	-0.15	(0.04)	**-0.26**	(0.172)	-0.24	(0.059)
	Primarily Marine	1.46	(0.174)	0.27	(0.023)	-0.97	(0.115)	**-1.99**	(0.094)	2.40	(0.514)	-0.03	(0.027)	-0.63	(0.141)	**-3.19**	(0.547)
Non Poor	Primarily Aquaculture	**-1.65**	(0.039)	-0.36	(0.038)	-0.23	(0.032)	0.75	(0.053)	**-1.44**	(0.463)	0.28	(0.234)	0.22	(0.168)	1.39	(0.245)
	Mixed	-0.10	(0.024)	**-0.69**	(0.025)	0.08	(0.016)	0.21	(0.014)	-0.58	(0.319)	**-1.02**	(0.155)	-0.49	(0.118)	-0.25	(0.122)
	Primarily Inland Capture	0.11	(0.063)	-0.03	(0.035)	**0.04**	(0.065)	-0.68	(0.04)	1.99	(1.726)	0.72	(0.817)	**0.70**	(0.682)	0.41	(0.593)
	Primarily Marine	2.02	(0.176)	0.22	(0.023)	-1.39	(0.122)	**-2.25**	(0.104)	2.02	(0.704)	-0.16	(0.077)	-0.70	(0.23)	**-3.17**	(0.714)

		Rural								Urban							
2005 Price Elasticities		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE	Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-1.73**	(0.027)	-0.17	(0.012)	0.34	(0.014)	0.36	(0.016)	**-1.73**	(0.028)	-0.08	(0.007)	0.30	(0.013)	0.50	(0.021)
	Mixed	-0.02	(0.012)	**-1.05**	(0.025)	0.01	(0.005)	0.28	(0.019)	0.00	(0.014)	**-1.13**	(0.051)	0.01	(0.023)	0.41	(0.035)
	Primarily Inland Capture	0.62	(0.028)	-0.01	(0.007)	**-1.14**	(0.006)	-0.37	(0.016)	0.52	(0.028)	-0.08	(0.027)	**-1.33**	(0.018)	-0.15	(0.015)
	Primarily Marine	1.03	(0.069)	0.62	(0.043)	-0.75	(0.047)	**-2.16**	(0.075)	1.19	(0.11)	0.57	(0.065)	-0.33	(0.033)	**-2.96**	(0.155)
Non Poor	Primarily Aquaculture	**-1.58**	(0.019)	-0.22	(0.011)	0.30	(0.011)	0.35	(0.014)	**-1.69**	(0.028)	-0.18	(0.01)	0.35	(0.014)	0.55	(0.022)
	Inland Capture &Aquaculture	-0.10	(0.009)	**-0.84**	(0.02)	0.003	(0.003)	0.23	(0.012)	-0.11	(0.014)	**-0.69**	(0.045)	-0.12	(0.02)	0.38	(0.036)
	Primarily Inland Capture	0.75	(0.029)	-0.07	(0.007)	**-1.18**	(0.008)	-0.45	(0.018)	0.61	(0.027)	-0.28	(0.024)	**-1.31**	(0.022)	-0.12	(0.015)
	Primarily Marine	1.10	(0.079)	0.42	(0.036)	-0.75	(0.046)	**-2.11**	(0.061)	0.92	(0.066)	0.34	(0.039)	-0.25	(0.023)	**-2.53**	(0.093)

		Rural								Urban							
2010 Price Elasticities		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine		Primarily Aquaculture	SE	Mixed	SE	Primarily Inland Capture	SE	Primarily Marine	SE
Poor	Primarily Aquaculture	**-1.92**	(0.043)	0.05	(0.003)	0.58	(0.026)	0.39	(0.017)	**-0.81**	(0.012)	-0.21	(0.011)	0.20	(0.01)	0.24	(0.02)
	Mixed	0.12	(0.008)	**-1.03**	(0.003)	0.10	(0.005)	0.06	(0.003)	-0.24	(0.014)	**-0.63**	(0.024)	0.16	(0.01)	0.15	(0.013)
	Primarily Inland Capture	1.06	(0.052)	0.10	(0.005)	**-2.00**	(0.044)	-0.14	(0.007)	0.26	(0.017)	0.14	(0.01)	**-1.42**	(0.023)	0.00	(0.006)
	Primarily Marine	0.56	(0.026)	-0.16	(0.014)	-0.28	(0.014)	**-1.84**	(0.043)	-0.17	(0.049)	-0.33	(0.034)	-0.23	(0.021)	**-2.00**	(0.108)
Non Poor	Primarily Aquaculture	**-1.86**	(0.029)	0.06	(0.003)	0.57	(0.02)	0.39	(0.014)	**-0.65**	(0.016)	0.01	(0.292)	0.01	(0.246)	0.02	(0.016)
	Mixed	0.19	(0.009)	**-0.98**	(0.002)	0.14	(0.007)	0.06	(0.003)	-0.24	(0.011)	**-0.52**	(0.023)	0.22	(0.01)	0.14	(0.009)
	Primarily Inland Capture	1.17	(0.049)	0.12	(0.005)	**-2.11**	(0.047)	-0.17	(0.008)	0.35	(0.015)	0.20	(0.009)	**-1.44**	(0.016)	-0.02	(0.004)
	Primarily Marine	0.56	(0.036)	-0.35	(0.027)	-0.41	(0.029)	**-2.00**	(0.068)	-0.48	(0.054)	-0.49	(0.046)	-0.33	(0.032)	**-1.60**	(0.068)

Source: Authors' calculations from HIES 2000, 2005, and 2010

Table A.10: Model calibration

	Price target growth rate	Current sim price growth rate	Historical production growth rate	Current sim prod. growth rate	Current prod. shock	Current elast. of supply	Sim price change	Price error	Prod. error
Aquaculture	-2.00%	-5.24%	8.61%	6.72%	0.08	0.4	-5.28%	-3.31%	-1.74%
Inland capture	-2.00%	-1.49%	2.13%	1.97%	0.021	0.3	-1.52%	0.52%	-0.15%
Mixed	-2.00%	-3.19%	-0.12%	4.34%	0.08	0.3	-3.19%	-1.21%	4.47%
Marine	0.30%	-0.30%	3.01%	1.10%	0.03	0.3	-0.30%	-0.60%	-1.85%

Note: All growth rates and changes are from 2010–2015

Source: Authors' calculations from simulations

Table A.11: Bangladesh fish production and prices: Simulation results (alternative parameters)

	Aquaculture	Inland capture	Mixed	Marine	Total fish
Annual growth rates: 2015–2030					
Production					
	Aquaculture	**Inland capture**	**Mixed**	**Marine**	**Total fish**
Base 2015 level	1542.2	462.7	1009.3	494.8	3509.0
Growth rates					
Base	3.23%	1.39%	1.63%	1.31%	2.31%
Sim 1	4.27%	1.80%	1.96%	1.25%	2.96%
Sim 2	3.72%	1.83%	2.01%	1.68%	2.75%
Sim 3	4.76%	2.24%	2.34%	1.62%	3.41%
Sim 4	5.04%	1.75%	1.93%	1.21%	3.36%
Sim 5	5.53%	2.19%	2.30%	1.58%	3.81%
Price					
	Aquaculture	**Inland capture**	**Mixed**	**Marine**	**Average fish**
Base 2015 level	103.99	127.61	109.01	220.20	140.2
Growth rates					
Base	-1.04%	4.71%	0.43%	4.43%	3.4%
Sim 1	-2.51%	3.33%	-0.44%	4.23%	2.8%
Sim 2	0.14%	6.23%	1.68%	5.71%	4.8%
Sim 3	-1.34%	4.84%	0.79%	5.50%	4.1%
Sim 4	-3.77%	3.18%	-0.56%	4.10%	2.6%
Sim 5	-2.62%	4.68%	0.67%	5.36%	3.9%

Notes: Sim 1: High productivity, all systems.
Sim 2: Increased household fish demand.
Sim 3: Sim 1 with increased household demand.
Sim 4: Sim 1 with extra aquaculture productivity gains.
Sim 5: Sim 4 with increased household demand.

Source: Model simulations.

Table A.12: Bangladesh fish consumption: Simulation results (alternative parameters)

		Aquaculture	Inland capture	Mixed	Marine	All fish
Per capita consumption						
Base 2015	**Level (kg per capita)**					
	Rural nonpoor	11.67	2.36	5.72	1.77	21.52
	Rural poor	7.03	1.90	4.25	0.89	14.07
	Urban nonpoor	12.30	3.61	6.77	5.72	28.40
	Urban poor	9.77	2.78	5.69	2.59	20.83
	All Bangladesh	9.78	2.43	5.33	2.15	19.69
Percent change 2015–2030						
Base	Rural nonpoor	6.7%	-21.3%	0.3%	-18.4%	0%
	Rural poor	19.9%	-13.4%	8.4%	-8.1%	10%
	Urban nonpoor	51.4%	15.5%	8.2%	-3.4%	25%
	Urban poor	69.9%	36.0%	21.0%	23.4%	46%
	Total	33.7%	6.0%	10.4%	9.1%	21%
Sim 3	Rural nonpoor	47.5%	-4.6%	25.2%	-2.6%	32%
	Rural poor	56.4%	3.6%	28.6%	6.6%	38%
	Urban nonpoor	90.7%	39.7%	14.7%	2.2%	48%
	Urban poor	71.4%	37.0%	16.5%	14.5%	45%
	Total	66.8%	22.4%	24.4%	15.9%	44%
Sim 5	Rural nonpoor	64.4%	-5.4%	23.7%	-5.2%	40%
	Rural poor	72.9%	3.2%	28.6%	4.3%	46%
	Urban nonpoor	114.4%	38.6%	13.7%	2.7%	58%
	Urban poor	92.0%	35.6%	16.3%	13.1%	54%
	Total	86.2%	21.5%	23.6%	15.0%	53%

Notes: Sim 1: High productivity, all systems.
Sim 2: Increased household fish demand.
Sim 3: Sim 1 with increased household demand.
Sim 4: Sim 1 with extra aquaculture productivity gains.
Sim 5: Sim 4 with increased household demand.

Source: Model simulations.

Table A.13: Bangladesh fish production projections to 2015 (Dorosh 2006)

	1995/96	2000/01	2014/15	Growth Rates 1996–2001	Growth Rates 2001–2015
Inland capture	1,366	950	344	-7.00%	-7.00%
Inland culture	317	651	2,471	15.50%	10.00%
Marine	628	597	519	-1.00%	-1.00%
Total	*2,311*	*2,198*	*3,334*	*-1.00%*	*3.00%*

Notes: Projections for 2014/15 assume no change in real prices of fish.; Inland culture is Department of Fisheries data.; Inland capture is residual of Household Expenditure Survey (HES) data of total fish less DOF inland culture.; Marine is HES consumption figure for dried fish (10:1 fresh to dry conversion).; 1995/96 and 2000/01 are historical data; 2014/15 is a projection.

Source: FSR (2003) and authors' calculations.

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