Market Integration between Cultured and Captured Species in Developing Countries: Lessons from Inland Areas in Bangladesh

Afjal Hossain, *University of Copenhagen*; Max Nielsen, *University of Copenhagen*; Isaac Ankamah-Yeboah, *University of Ghana*; Badiuzzaman, *Patuakhali Science and Technology University*; Fakir Azmal Huda, *Bangladesh Agricultural University*

ABSTRACT

The study tested market integration between cultured fish (tilapia and pangasius) against captured fish (hilsa, swamp barb, prawn, wallago, and long-whiskered catfish) in the domestic market of Bangladesh. The Johansen cointegration framework was applied to identify market integration between cultured and captured species using monthly wholesale price data for the period January 2010 to May 2017. The study showed that the law of one price was rejected in all market pairs except the pangasius and long-whiskered catfish pair, suggesting imperfectly integrated markets. The study revealed mixed evidence of weak exogeneity tests, including cultured and captured led markets as well as bidirectional relationships. Given the fact that cultured fish accounts for a substantial market share, the implication is that the supply growth of aquaculture, all other things being equal, reduces captured fish prices and, subsequently, reduces overexploitation, overcapacity, and the number of fishers in a situation where overexploitation is prevalent. This appears to lead to a double gain in the long run, with fish farmers producing and fishers catching more fish.

Key words: Captured fish, competition, cultured fish, error correction model, law of one price, market integration, vector.
JEL codes: C22, P22, Q22.

INTRODUCTION

Fish is a core item of the diet in Bangladesh, as reflected in the Bangla saying, "Rice and fish makes one a Bengali." The per capita fish consumption in Bangladesh has increased from 11.3 to 19.7 kg in the period from 1964 to 2015. Per capita fish consumption is thus slightly higher than the average of other developing countries, which was 19.3 kg in 2015 (FAO 2018; Needham and Funge-Smith 2015; WorldFish 2019). Fish plays important role by being a source of calories and animal protein. Fish alone contributes 52% of animal calories (Toufique, Farook, and Belton 2018) and almost 60% of the human intake of animal protein in Bangladesh (Sapkota et al. 2015). It is also

Afjal Hossain is a PhD student, University of Copenhagen, and Department of Marketing, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh (email: hossainafjal@gmail.com). **Max Nielsen** is an associate professor, University of Copenhagen, Rolighedsvej 25, 1958, Frederiksberg C. Denmark (email: max@ifro.ku.dk). **Isaac Ankamah-Yeboah** is a lecturer, University of Ghana, Box 68, Legon-Accra, Ghana (email: iankamahyeboah@ug.edu.gh). **Badiuzzaman** is a professor, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh (email: bzaman_pstu@yahoo.com). **Fakir Azmal Huda** is a professor, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh (email: fahmithus@hotmail.com).

The authors would like to thank the Danish International Development Agency for its financial support through BANGFISH to the project entitled Upgrading Pangasius and Tilapia Value Chains in Bangladesh, number F38A26778.

Received February 6, 2020; Accepted September 30, 2020; Published online March 19, 2021. http://dx.doi.org/10.1086/712802

Marine Resource Economics, volume 36, number 2.
0738-1360/2021/3602-0003$10.00

the most important supplier of essential fatty acids and different micronutrients (Roos et al. 2007). Therefore, fish consumption is an important dietary component in Bangladesh.

Historically, fish in Bangladesh has been supplied mostly from inland capture fisheries that consist mainly of freshwater fish (Bartley et al. 2015; Fernando 1994). While supplying fish through inland capture fisheries remains prevalent today, farming of seafood (fish and crustaceans) grew by 9.2% annually over the period between 1996 and 2016 (FAO 2019a) and is now the main source of seafood with approximately 57% share (DoF 2017). Inland capture fisheries production has decreased by 15% from 2009 to 2016 because of overexploitation (FAO 2019b). On the other hand, the contribution of aquaculture has doubled at the same time (FAO 2019a, 2019b). With the increases in per capita fish consumption, the growth of aquaculture has filled the gap of captured fish landings. Therefore, market integration between captured and cultured fish species is expected in the Bangladeshi fish market. This study examines the effects of continuous aquaculture growth on inland fisheries in Bangladesh by testing the market integration between the two cultured species, pangasius and tilapia, and the five captured species, hilsa, swamp barb, prawn, wallago, and long-whiskered catfish.

Specifically, this study tests market integration between cultured and captured species in different wholesale markets in Dhaka, Bangladesh, to infer the effects of aquaculture supply growth on inland fisheries. The study is relevant because in a developing country like Bangladesh, capture fisheries are often overexploited because of open-access or regulated open-access (Homans and Wilen 1997) along with the additional efforts inducing extra costs. This leads to reduced catches in the long run and encourages the development of aquaculture since only supplies of farmed fish are able to meet demand. If market integration exists, growth in aquaculture, all other factors being equal, induces price reductions not only in aquaculture, but also in fisheries. This has benefits such as increased long-term sustainable harvests of the regulated open-access fisheries by reducing overexploitation, overcapacity, and the number of fishers. Income of fishers may increase or decrease, dependent on the size of the price reduction. If price reductions are small, income ceteris paribus grows with the larger catches. If price reductions are sufficiently large, income will fall. Own price flexibilities of demand measure the effect on prices when catches change. While no inverse demand studies are known from the Bangladeshi fish market, own price flexibilities on fish in other countries are identified in the range between −1 and 0 (Barten and Bettendorf 1989; Burton 1992; Ioannidis and Whitmarsh 1987; Jaffry, Pascoe, and Robinson 1997; Nielsen 2005). If that applies in Bangladesh, income of fishers ceteris paribus grows with increased catches. Fishers do not leave the industry unless the profit of the marginal fishers is zero. In the absence of market integration, inland fisheries remain unaffected by aquaculture.

Aquaculture and inland capture fisheries are important in Bangladesh, contributing a total of 3.2 million tonnes of seafood in 2016. Of the total seafood supply in Bangladesh, 27% came from inland capture fisheries and 56% from aquaculture (FAO 2019a, 2019b). Globally, Bangladesh is ranked third and sixth position, respectively, in inland fisheries and aquaculture (FAO 2019a, 2019b), with largely no seafood imports and other than shrimp, largely no seafood exports. Inland fisheries supply at least 15% of total fish catches (likely more as the numbers are underreported) of the world (FAO 2018). Thus, inland fisheries are important both in Bangladesh and in a global context. Knowledge of the stakeholders in developing inland fisheries is, therefore, important.

The issue of fish market integration in developing countries is interesting because fish is an important part of the diet and studies of fish market integration in developing countries are mostly nonexistent. Bangladesh, in particular, is an interesting case because only 15% of the total seafood production is exported, and almost no export of the species is analyzed in the study. Hence, Bangladesh presents a strong domestic market, supplied by both fisheries and aquaculture, for analysis.

Three different strands of literature prevail in studying market interactions between captured and cultured fish species. One strand of literature encompasses theoretical studies on market integration between cultured and captured fish. Anderson (1985) and Valderrama and Anderson (2010) studied the effects of aquaculture growth on commercial fisheries, and Jensen, Nielsen, and Nielsen (2014) examined whether aquaculture may be influenced by improved fisheries management.

Anderson (1985) used a bioeconomic model in his study assuming that there is a perfect substitution between farmed fish and wild fish. He found that when farmed fish have noticeable market shares, growth in aquaculture reduced the prices of wild fish, thereby reducing overexploitation, overcapacity, and the number of fishers. Hence, this results in both growing production at fish farms and growing steady harvest. With many inland fisheries in developing countries, including Bangladesh, being open-access or regulated open-access in the form of regulated open-access, it is expected that when cultured fish have a noticeable market share, aquaculture supply growth will result in this double gain, if the markets for captured and cultured species are integrated. This paper contributes to the literature by showing market integration between farmed and wild fish markets in Bangladesh and thereby identifying an example where the theoretical finding of Anderson (1985) applies.

A second strand of literature is concerned with empirical studies of market integration between farmed fish and wild fish in developed countries. Virtanen et al. (2005) found that there is market integration between imported salmon from Norway and farmed salmon and salmon trout in the Finnish fish market. Nielsen et al. (2007) studied integration between farmed trout and five other fish in Germany. The study found that the market for trout is integrated with all captured fish except salmon. Nielsen, Smit, and Guillen (2009) investigated market integration for several fresh and frozen fish species in Europe and found that markets are integrated, except for shrimp, whereas Norman-Lopez (2009) and Norman-Lopez and Asche (2008) investigated the market integration between farmed and wild fish in the US market. Norman-Lopez found that there is market integration between farmed tilapia and wild fish and stated that the tilapia market is different from those of other farmed fish. Asche, Bjørndal, and Young (2001) found market integration between farmed and wild salmon in the European Union and the United States. Nielsen et al. (2011) also identified market integration between farmed and wild fish in Germany. Ankamah-Yeboah, Ståhl, and Nielsen (2017) showed that market integration has been confirmed in most of the cases analyzing cold- and warm-water shrimp in the European value chain, whereas Nielsen et al. (2018) investigated the northern shrimp value chain and found nodes of the shrimp value chain to be integrated. Ankamah-Yeboah and Bronnmann (2018) identified market integration for shrimp and lobster in the German crustacean market. Bjørndal and Guillen (2017) found market integration between wild and farmed conspecifics for blackspot seabream and Atlantic cod in Spain. For middle-income countries, Bayramoglu (2019) found market integration between farmed sea bream and wild sea bream in Turkey, while Pincinato and Asche (2016) found market integration between wild and farmed shrimp in Brazil. To the knowledge of the authors, this study is the first to identify market integration between captured and cultured fish species in a developing country. Furthermore, it is the first to study and identify market integration between cultured species and fish caught in inland fisheries.

In the next section, we provide a case of inland fisheries and aquaculture in Bangladesh. We then present the methodology of this study, followed by presentation and discussion of data and the results. We end with conclusions of this study.

A CASE ON INLAND FISHERIES AND AQUACULTURE IN BANGLADESH

Bangladesh has achieved remarkable growth in the aquaculture and fisheries sector since its independence in 1971, as revealed in figure 1. In 2015, more than 18 million people depended on the fisheries sector for their daily livelihood (DoF 2016). This sector constitutes 4% of the GDP of Bangladesh, compared with 13% from the remaining agriculture sector (BER 2018).

In Bangladesh, there are three types of fishery resources: marine, and two types of inland fisheries: capture and aquaculture. Inland fish catches (from both capture and aquaculture) contributed 83% of the total supply of fish in Bangladesh in 2016, whereas marine fishery resources contributed only 17% (FAO 2019a, 2019b). Inland fishers work at the rivers, estuaries, beels, floodplains, Sundarbans, and Kaptai Lake. The total area of inland fisheries is 4.7 million hectares (DoF 2018).

Two hundred and sixty freshwater fish species are caught in inland fisheries in Bangladesh; the major ones are carp, catfish, snakehead, and hilsa. In addition, 25 species of prawn and shrimp are caught in inland and marine areas (DoF 2016) by various types of fishing gear such as gill nets, drag nets, and traps (Islam, Jahan, and Al-Amin 2016).

The most prominent species of fish caught inland is hilsa (*Tenualosa ilisha*), the national fish of Bangladesh. In 2017, inland fisheries reported catches of approximately 217,000 tonnes (DoF 2017). Catches of hilsa have tripled since 2002, as shown in figure 2.

Other important species for inland fisheries include swamp barb (*Puntius chola*), with total catches of 89,000 tonnes in 2017 on an upward trend, and prawn (*Macrobrachium lamarrei*) with 64,000 tonnes. Catches of long-whiskered catfish (*Sperata aor*) and wallago (*Wallago attu*)

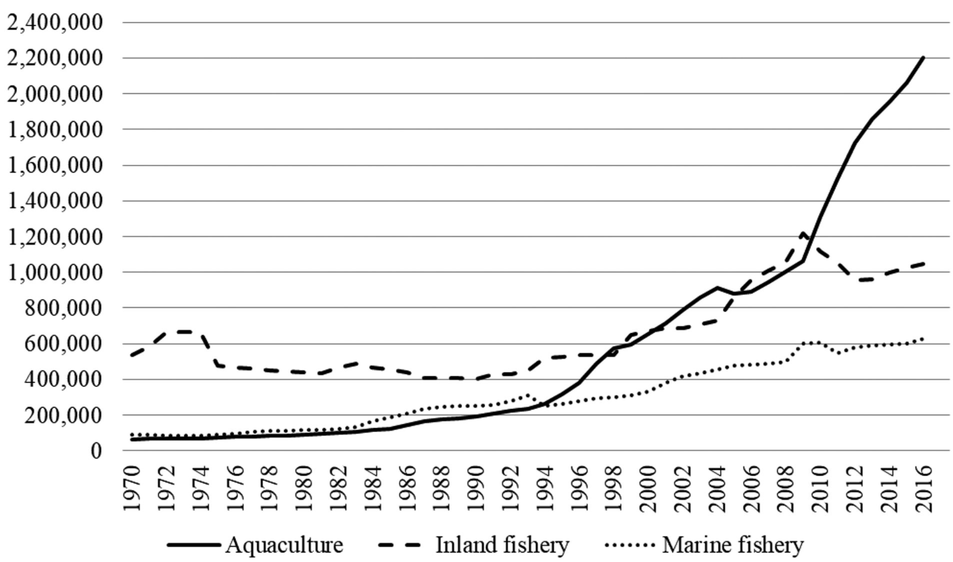

Figure 1. Fisheries Production (in tonnes) in Bangladesh, 1970–2016. A color version of this figure is available online.

Source: Authors' representation based on data from FAO (2019a, 2019b).

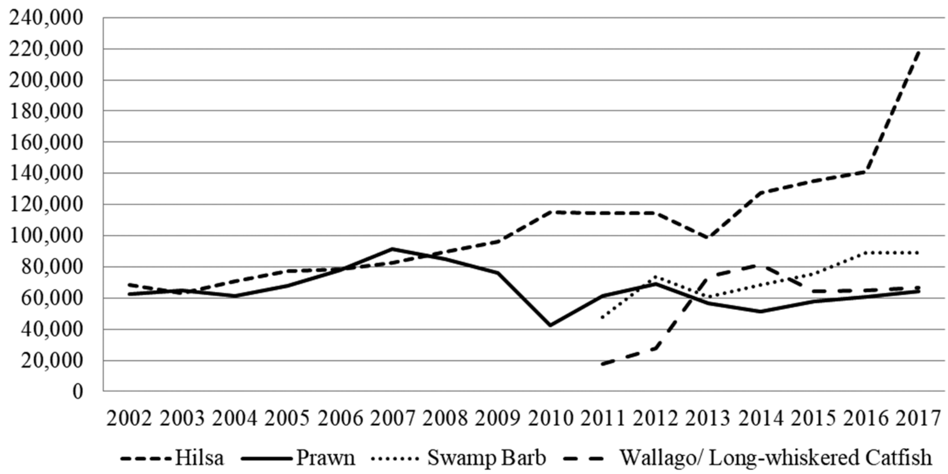

Figure 2. Catches of the Main Inland Fish Species (in tonnes) in Bangladesh, 2002–17. A color version of this figure is available online.

Source: DoF (2002–17).

have fluctuated over time, but the species remain important with a total contribution of just over 60,000 tonnes in 2017.

Shamsuzzaman et al. (2017) presented a biological stock assessment from Bangladesh, but this only includes marine fish stocks. To the knowledge of the authors, a biological assessment of inland fish stocks does not exist in the literature. Moreover, while time series data for the number of inland fishers do not exist, the number was 3.3 million in 2017 and 3.1 million in 2005 (DoF 2017). With the substantial increase in catches of hilsa, as well as increases in catching swamp barb and fluctuations for long-whiskered catfish and wallago, and with most fish sold in the market being immature (Amin et al. 2008; Islam et al. 2017), overexploitation may prevail. Hence, despite the lack of detailed information, there are weak indications of overexploitation of hilsa and swamp barb, and possibly of other species, implying that initial fishing effort may correspond to a level above the maximum sustainable yield.

At present, 12 laws on aquaculture and fisheries prevail in Bangladesh, some of which are implemented to manage the fisheries sector. The Protection and Conservation of Fish Act (1950) with an Amendment Ordinance (1982) forms the legal framework for inland fisheries in Bangladesh, together with the implementation rules, Protection and Conservation of Fish Rules (1985). The implementation rules basically protect certain carp species and promote their production and growth. Since inland capture fishery in Bangladesh is poorly managed and lacks licensing requirements, output limitations, and property rights, fishers try to capture more fish with additional efforts that induce extra costs. Thereby, price reductions resulting from growing aquaculture imply that fishers earn less in the long run and that some fishers therefore leave the fishery. The result is reduced overcapacity and reduced overexploitation. Furthermore, the Bangladesh government in 2016 adopted a program to conserve and protect juvenile/immature hilsa of up to 25 cm and mother hilsa during the spawning season of February to May (DoF 2016). The program prohibits mesh sizes less than 4.5 cm, introduces a minimum size limit of hilsa (i.e., 25 cm), and bans fishing of hilsa at their spawning grounds (six hilsa fish sanctuaries) during this period. Catching, carrying, transporting, offering, selling, bartering, exposing, or possessing is also prohibited. In return, the government provides fishers with an allowance of 40 kg of food grain per household per month during this period (MoF 2015). The government recently declared that all the fishing nets used without obeying the protection and conservation rules (Protection and Conservation of Fish Rules 1985, 12[b]) will be confiscated. A person is punishable by fines and imprisonment for one to three years if caught violating these rules. Hence, while some conservation measures are in force, they cover only hilsa fishery, and the absence of licensing requirements and output restrictions makes regulated open-access the most proper characterization of the fishery among the four types of regulations (open-access, regulated open-access, restricted open-access, and optimal management, mentioned by Homans and Wilen [1997]). Aquaculture in Bangladesh started in the late 1960s with large-scale carp cultures in ponds and lakes (FAO 2019c). Aquaculture includes fish farming in ponds, seasonal water bodies, oxbow lakes, *gher*, and pen and cage cultures. It covers 800,000 hectares. Only freshwater and coastal aquaculture is carried out in Bangladesh. Freshwater aquaculture consists of mainly pond aquaculture, whereas coastal aquaculture consists of mainly shrimp farming. Pond aquaculture is polyculture in nature, where native and exotic species are farmed. Aquaculture is operated all over the country, with the largest production being carried out in Mymensingh, Jessore, and Comilla. About 15 million people are involved in this sector (Hossain 2014). Generally, extensive production systems are used, but semi-intensive and intensive systems also exist.

In 2015, the per capita fish consumption in Bangladesh increased up to 19.7 kg, which is very close to the global average of 20.2 kg (FAO 2018). This increase was possible only because production of fish from aquaculture grew by 121% in nine years (Toufique, Farook, and Belton 2018). Moreover, consumption of fish from aquaculture is higher than that of any other category of fish because of its cheaper price. According to Hernandez et al. (2018), the farmed fish market grew by 25 times in the last three decades. Pangasius (*Pangasius pangasius* or *Pangasianodon hypopthalmus*) and tilapia (*Oreochromis mossambicus* or *Oreochromis niloticus*) are, economically, the most important species of aquaculture production (Alam 2011). The aquaculture production of pangasius and tilapia were 510,000 tonnes and 370,000 tonnes, respectively, in 2017 (DoF 2017), with respective annual growth rates of 22% and 23% since 2010.

Fish markets are available both in the large cities and in the countryside in Bangladesh. Basically, the four types of domestic seafood markets in Bangladesh are primary markets (markets that are located at the source of production), secondary markets (markets that are located usually in the subdistrict headquarters), higher secondary markets (markets that are located in big cities), and retail markets. The bulk of the fish sold in these markets is unprocessed (Sapkota et al. 2015).

About 97% of fish supplied from both aquaculture and inland fisheries are sold for domestic consumption (Hasan 2001). The market for freshwater fish caught in Bangladesh, therefore, appears disconnected from international fish markets. The lack of exports is due to minimum quality requirements at the large whitefish markets in Europe, the US, and Japan (Dey et al. 2005). However, since exports may target other countries, international prices may set an upper threshold for the prices in Bangladesh.

METHODS

This study assesses the price competition between cultured and captured species (caught in seasonal water bodies and rivers) based on a time series econometric model of market integration. Market integration is a popular test for examining the relationship between prices and detecting competition between different products in a market. In simple terms, market integration reveals whether price changes in two or more products follow each other over time. The economic theory behind market integration is found in the definition of a market: "the area within which the price of a good tends to uniformity, allowance being made for quality differences and transportation costs" (Stigler and Sherwin 1985, 555). Following this, the relationship between two prices (p_i, $i = 1, 2$) at time periods t can be investigated with the following equation:

$$\log p_{1t} = \alpha + \beta \log p_{2t} + \varepsilon_t, \tag{1}$$

where α is a constant term that may be interpreted as transportation costs and quality differences between the prices of product one and two. The error term ε_t is assumed to reflect measurement errors. The term β is the long-run coefficient between the prices, where $\beta = 0$ indicates that there is no relationship between the prices of product one and two and $\beta = 1$ indicates that the law of one price (LOP) holds and the relative prices are stable. In the latter case, the goods are perfect substitutes. If $0 < \beta < 1$, then the prices follow each other over time, but not perfectly. According to Ravallion (1986), lags can be introduced into equation 1 for its dynamic adjustment processes. However, the equation is valid only if the price series data are stationary. Hence, cointegration is mandatory for the nonstationary price series data (Asche, Gordon, and Hannesson 2004). The principle of the cointegration analysis is that a linear combination of time series integrated of order one is stationary.

To test for market integration, it is necessary to conduct the unit root test. It is used to check whether the series is stationary to avoid spurious regression results. This is often done with the standard augmented Dickey-Fuller (ADF) test (Dickey and Fuller 1979, 1981) for each series with restricted or unrestricted deterministic terms for price series in level and differences.

In this setting, the Johansen cointegration test (Johansen 1988; Johansen and Juselius 1990) was adopted to test for cointegration. The Johansen's cointegration test is based on an error correction model (ECM) representation of the vector autoregressive (VAR) model with the I(0) vector Δp_t containing the prices given by the following:

$$\Delta p_t = \sum_{i=1}^{k-1} \Gamma_i \Delta p_{t-i} + \Pi p_{t-1} + \mu + \varepsilon_t, \tag{2}$$

where the symbol Δ indicates first-difference operator. The matrix Π contains the parameters in the long-run relationships. If the cointegration matrix has reduced rank (i.e., $r < n$), where n is the number of variables included in the model and r is the rank of the matrix, then there exists $n \times r$ matrices α and β, each with rank r such that $\Pi = \alpha\beta'$ where α is the speed of adjustment, β is a matrix of the long-run coefficient, and $\beta' p_t$ is stationary. The test for weak exogeneity is $\alpha = 0$; in this case, if p_1 is weakly exogenous to p_2 ($\alpha_1 = 0$), then p_1 does not adjust to changes in p_2 and p_1 can be considered a market leader. The Johansen test for cointegration is based on two likelihood ratio statistics, namely the trace test and the maximum eigenvalue test. The null hypothesis of the two tests is that there are at most r cointegration vectors, such that $0 < r < n$. A rank of $r = 0$ indicates no cointegration, and $r = n$ indicates full rank, meaning that the series are stationary. For inference as market integration, $r = n - 1$ from the cointegration test is expected. The LOP is tested by imposing restrictions on β (Juselius 2006). The presence of cointegration in this bivariate system with rank $\Pi = 1$ implies that the cointegrated VECM of equation 2 can be decomposed as follows:

$$\begin{pmatrix} \Delta p_{1t} \\ \Delta p_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \left(p_{1t-1} - \alpha - \beta_{p2t-1} \right) + \begin{pmatrix} \theta_{1j} & \vartheta_{1j} \\ \theta_{2j} & \vartheta_{2j} \end{pmatrix} \begin{pmatrix} \Delta p_{1t-j} \\ \Delta p_{2t-j} \end{pmatrix} + \begin{pmatrix} e_{t1} \\ e_{t2} \end{pmatrix}, \tag{3}$$

where μ_i = the deterministic components (including monthly dummies and the intercept terms). The α_i is the decomposition of the loading matrix as defined above for the respective markets. The parameters θ_{ij} capture the effect of the short-run price changes. The error term, e_t, is assumed to be independent, to be identically distributed, and to have zero mean. The selected number of lags $j = 1, 2, \ldots, k$ is selected based on a well-specified model that ensures that there is no autocorrelation and heteroskedasticity. As shown in Emerson (2007), the cointegration model is sensitive to the number of lags chosen. To complement the ADF unit root test, we embark on a multivariate unit root test as shown in Hjalmarsson and Österholm (2010). This test can show whether the price variables in the model of cointegration have unit root at the same selected number of lags. The test is implemented by imposing the following restrictions on the β under the presence of bivariate cointegration: $\acute{\beta} = (1 \;\; 0)$ and $\acute{\beta} = (0 \;\; 1)$. This is a likelihood ratio test where rejection of the restrictions indicate nonstationarity of price one and two, respectively.

DATA

For the time series econometric modeling, data of a total of 89 observations on monthly wholesale prices in Dhaka during the period January 2010 to May 2017 were used. The data were collected from the website of the Department of Agricultural Marketing, Ministry of Agriculture of Bangladesh (DAM 2017). The nationwide terminal market of fish is located in Dhaka, the capital of Bangladesh. Every day, thousands of trucks supply fish products to the market from all over Bangladesh. Auctions of fish usually take place among *aratdars*, wholesalers, and retailers, beginning late at night and ending before sunrise. The most popular cultured fish, pangasius, is marketed live in water drums, while the other species examined in this study are marketed as both live whole fresh and on ice.

Table 1 presents the descriptive statistics of the nominal prices of seven fish species with average monthly prices in USD per kilogram. Hilsa is the most expensive fish of the chosen species on the Bangladeshi fish market, with an average price of $6.53/kg. Swamp barb, prawn, wallago, and long-whiskered catfish, with similar variations in prices, can be labeled as the ones from the middle price segment. The long-whiskered catfish price is the most volatile, with a coefficient of variation of 31%. This is followed by hilsa, with a price volatility explained by its seasonal nature. The majority of the five captured species are caught from June to October, which is considered the rainy season in Bangladesh. In this season, prices of these fish are lower than during the rest of the year. The cultured species, tilapia and pangasius, are the cheapest fish species and come with

Table 1. Summary Statistics of Nominal Prices (in USD/kg)

	Pangasius	Tilapia	Hilsa	Swamp Barb	Prawn	Wallago	Long-Whiskered Catfish
Mean	1.16	1.73	6.53	2.62	3.34	3.46	3.66
Median	1.21	1.72	6.29	2.94	3.47	3.24	4.05
Maximum	1.48	3.01	10.47	3.87	7.13	5.66	5.46
Minimum	0.82	1.01	2.30	0.68	2.14	1.66	0.97
Std. dev.	0.16	0.36	1.80	0.71	0.80	0.90	1.14
CoV (%)	14.03	20.99	27.58	27.18	24.09	25.90	31.45
Obs.	89	89	89	89	89	89	89

Source: Authors' estimation based on Department of Agricultural Marketing (2017).

the lowest price volatility because of the level of control in fish farming. All the species are chosen from among the highly preferred and consumed fish in Bangladesh. The species are also very common fish in the studied market of Bangladesh (Needham and Funge-Smith 2015).

Figure 3 presents the price development of the cultured fish species, pangasius and tilapia, in panel A and the five captured fish species, long-whiskered catfish, wallago, prawn, swamp barb, and hilsa, in panel B. The prices of the cultured species follow a similar trajectory over time with minor fluctuations. The prices of the captured species follow a general upward trend, with the trajectory of hilsa being much steeper than the rest. The reason for this trajectory remains speculative, but since hilsa is a luxury good, perhaps demand increased with the fast growth of GDP and income in Bangladesh.

Without foreign trade, prices are determined by domestic supply and demand. Increasing supply of inland capture fish induces, all other things equal, a downward pressure on the prices. If market integration exists, increased supply from aquaculture also induces a downward pressure on inland capture fish prices. Moreover, the simultaneous increases in supplies of inland capture fish and aquaculture, as well as in prices of inland capture fish (see figures 1–3), reveal increasing demand. This follows with both population and income growth, where income growth is reflected in the continued large growth rates of GDP.

The lack of foreign trade further implies that fish are both produced and consumed in Bangladesh and sold without competing imports. With the species sold unprocessed, the value chain is short and the wholesale prices analyzed reflect revealed demand from the final market.

RESULTS

To test for cointegration, the ADF test was used to check the unit roots on each of the price series. The ADF test specifications included models without trends (none), models with intercepts only, and models with intercepts and trends.

Table 2 presents the results of ADF test on log prices in level and in first difference. The values reported under different test specifications are the probability values of the ADF test statistics and their corresponding lags. As the first column of table 2 shows, the test for unit root failed to be rejected for all variables with the specification of "none" in levels, and was rejected at the 5% level for all in first differences. Similar results were found for the specification of "intercept

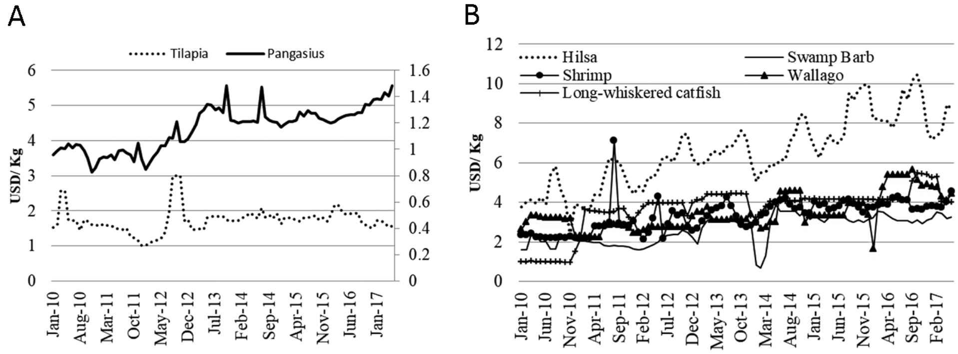

Figure 3. Price Development of Farmed and Wild Species (in USD/kg). (A) Farmed fish. (B) Wild fish. A color version of this figure is available online.

Source: Authors' representation based on Department of Agricultural Marketing (2017).

Table 2. Unit Root Test of Log Prices Using the Augmented Dickey-Fuller Test

	None		Intercept		Intercept + Trend	
Series	Prob.	Lag	Prob.	Lag	Prob.	Lag
Level						
LPangasius	0.963	1	0.765	1	0.445	1
LTilapia	0.555	3	0.028	0	0.088	0
LHilsa	0.865	0	0.670	8	0.017	0
LSwamp barb	0.740	2	0.159	3	0.011	0
LPrawn	0.904	3	0.250	8	0.538	10
LWallago	0.780	0	0.655	5	0.002	0
LLong-whiskered catfish	0.892	1	0.080	1	0.450	1
First difference						
D(LPangasius)	0.044	10	0.000	0	0.000	0
D(LTilapia)	0.000	1	0.000	1	0.000	1
D(LHilsa)	0.000	0	0.000	0	0.000	0
D(LSwamp barb)	0.000	0	0.000	0	0.000	0
D(LPrawn)	0.000	0	0.000	0	0.000	0
D(LWallago)	0.000	0	0.000	0	0.000	0
D(LLong-whiskered catfish)	0.000	1	0.000	1	0.000	1

Note: Reported values are the probability values of the ADF *t*-statistic. Optimal lags selected with modified Hannan-Quinn criterion. Source: Authors' estimation.

only," with the exception of tilapia, and for the specification of "intercept and trend," with the exception of hilsa, swamp barb, and wallago. Consequently, there is some evidence of unit roots. On this basis, the cointegration test will reveal whether the series are driven by stationary or nonstationary processes.

Table 3 presents the results of Johansen cointegration rank tests and the likelihood ratio (LR) test of the law of one price. The lag length used was selected with the modified Hannan-Quinn

Table 3. Johansen Cointegration Rank Test

		Trace		Max			LR-Stat	LR-Stat (Unit Root)	
Markets	Specification	$r = 0$	$r = 1$	$r = 0$	$r = 1$	β	$\beta = 1$	$\beta' = (1\ 0)$	$\beta' = (1\ 0)$
Tilapia vs.:									
Hilsa	1MD(9)	15.25**	1.45	13.80**	1.45	0.76	7.34*	5.25**	5.69**
Swamp barb	3MD(4)	36.66*	0.97	35.69*	0.97	0.49	21.97*	23.12*	34.65*
Prawn	1MD(10)	13.74**	0.02	13.73**	0.02	0.87	13.36*	11.62*	11.91*
Wallago	–	–	–	–	–	–	–	–	
Long-whiskered catfish	1MD(9)	22.45*	0.82	21.63*	0.82	0.85	20.77*	20.50*	20.62*
Pangasius vs.:									
Hilsa	2M(10)	80.26*	7.76	72.50*	7.76	0.29	37.84*	7.23*	22.96*
Swamp barb	$1M_7(1)$	33.88*	2.28	31.60*	2.28	0.85	27.57*	29.31*	29.30*
Prawn	1M(5)	15.57**	2.71	12.86**	2.71	0.81	10.08*	10.14*	10.15*
Wallago	1M(10)	17.84*	2.36	15.47*	2.36	0.82	9.88*	11.13*	10.91*
Long-whiskered catfish	2MD(4)	26.55*	2.16	24.39*	2.16	1.38	2.23	21.77*	7.81*

Note: The LR-stat column is the likelihood ratio (LR) statistic. Subscript 7 indicates that only month 7 was included in the model and is the only significant month. ** and * indicate statistical significance at the 5% and 10% levels, respectively. Source: Authors' estimations.

information criteria. In the column labeled "specification," the numbers indicate one of the five deterministic trend specifications.[1] The M indicates the inclusion of monthly seasonal dummies, and the D represents the inclusion of outlier dummies. The lags used are in parentheses. For example, 1MD(9) indicates a model estimated without intercept and trend in the cointegration equation and in the vector autoregressive model, with seasonal and outlier dummies, using a lag length of 9. The selection of lags is based on a length that ensures a well-specified model with the absence of serial correlation and heteroskedasticity. At the selected lags, a multivariate unit root test was implemented to complement the ADF unit root test; these are shown in the last two columns of table 3 with the restrictions $\acute{\beta} = (1\ 0)$ and $\acute{\beta} = (0\ 1)$. As can be seen, these restrictions are significantly rejected at the 5% level, indicating that the prices are nonstationary. This result implies that using cointegration under the assumption of nonstationary price series is justified despite the minor conflicting evidence for some variables emerging from the intercept and trend ADF specification.

The cointegration test is based on a pairwise analysis of two cultured species against five captured species (10 pairwise combinations). Results show that the first null hypothesis, $r = 0$ (no cointegration), is rejected for all pairs and the second null hypothesis, $r = 1$ (cointegration), is not rejected in any of the cases, except for tilapia and wallago. This indicates that there is a cointegration relationship between the respective species. Therefore, market integration exists in the bivariate model (Nielsen, Smit, and Guillen 2009). Tilapia is found to be integrated with four of the captured species, with the sole exception of wallago where a cointegration relationship between tilapia and wallago is not identified. The same results were found for pangasius. On this basis, it is concluded that the Bangladesh terminal fish market can be categorized by integration between cultured and captured fish species. The implication is that the price of hilsa is reduced when supply is large during the hilsa season. So, the consumers of pangasius and tilapia may substitute with hilsa because of its reduced price. A similar conclusion can be drawn for long-whiskered catfish. Finally, the growth of pangasius and tilapia farming also induces price reductions of long-whiskered catfish, implying that consumers buy this fish instead.

The value of the LR test statistic of the LOP is shown in the third column of table 3 from the right. The LOP is used to describe the degree of market integration. Results show that LOP is rejected for all market pairs at the 5% significance level, except for the pairing of pangasius and long-whiskered catfish. On this basis, it can be concluded that, with the exception of pangasius and long-whiskered catfish, the price series of all the fish species develop to be relative equal over time, but their relative prices are not constant. Pangasius and long-whiskered catfish are perfect substitutes, while the remaining pairs are imperfect substitutes. Nielsen et al. (2007) found markets for farmed trout and captured cod to be perfectly integrated, because there is a similarity between these two species in size and color. On the other hand, Norman-Lopez (2009) found imperfect market integration between farmed tilapia and wild fish species in the United States.

Table 4 presents the results of the vector error correction model and misspecification tests. The first column, labeled α, shows the speed of adjustment parameters. The final three columns show results of VECM and misspecification tests. Misspecification tests include serial correlation (denoted LM) and autoregressive conditional heteroskedasticity (ARCH) with the null of

1. In this column, the initial numbers denote the following specifications in the cointegration equation and vector error correction model: 1 = without intercept or trend, 2 = with intercept and no trend, 3 = with intercept and no linear trend, 4 = with intercept and linear trend, and 5 = with intercept and quadratic trend.

Table 4. Results of the Vector Error Correction Model and Misspecification Tests

Market Pairs		α	X^2 Stat ($\Delta L\theta ij$)	P-Value (LM (12))	P-Value ($\sigma^2_{e,t} = \sigma^2$)
1	Tilapia	–0.10**	5.79	0.21	0.09
	Hilsa	0.11*	31.88*		
2	Tilapia	–0.54*	3.33	0.11	0.15
	Swamp barb	0.04	7.18		
3	Tilapia	–0.07	19.41**	0.26	0.10
	Prawn	0.31*	9.84		
4	Tilapia	–	–	–	–
	Wallago	–	–	–	–
5	Tilapia	–0.12	3.55	0.33	0.12
	Long-whiskered catfish	0.28*	24.73*		
6	Pangasius	–0.18*	10.79	0.06	0.16
	Hilsa	–0.51*	11.42		
7	Pangasius	–0.01	0.00	0.57	0.67
	Swamp barb	0.54*	0.02		
8	Pangasius	–0.07	4.25	0.48	0.30
	Prawn	0.63*	2.64		
9	Pangasius	–0.18*	8.09	0.50	0.42
	Wallago	0.17	4.29		
10	Pangasius	–0.14*	4.00	0.09	0.48
	Long-whiskered catfish	0.17*	13.65*		

Note: ** and * indicate statistical significance at the 5% and 10% levels, respectively. Source: Authors' estimations.

constant variance ($\sigma^2_{e,t} = \sigma^2$). The LM test of serial correlation is reported at the 12th lag. The probability values reported for LM and ARCH show no evidence of misspecification. The level of significance identifies weak exogeneity tests of the respective markets. Based on the α results found in table 4, three patterns of relationship are formed between cultured and captured fish species. The first is that the cultured species are weakly exogenous if the speed of the adjustment parameter is insignificant. The second is that the captured species is weakly exogenous. The third is that significant interaction occurs from both markets. For the existence of cointegration, at least one of the figures in α must differ significantly from zero.

Considering pairs between cultured tilapia and the captured species, it is observed that both tilapia and hilsa have significant speed of adjustment parameters, indicating that the prices in each market are determined by each other. Thus, each market reacts to shocks from the other. Tilapia is, however, weakly exogenous to prawn and long-whiskered catfish. This implies that the prices of tilapia do not respond to shocks from these captured species, and that the prices are determined on the tilapia market. Between tilapia and swamp barb, it can be observed that swamp barb is weakly exogenous and is the market leader because it determines the prices of tilapia.

Again, considering pairs between cultured pangasius and the captured species, it is seen that the adjustment parameter is significant for pangasius but not for wallago (pair 9). It indicates that wallago is weakly exogenous. Wallago is the market leader and pangasius is the market follower. Thus, prices of pangasius are determined based on the wallago market. In pair 7 (pangasius and swamp barb) and pair 8 (pangasius and prawn), it appears that pangasius is the market leader, while swamp barb and prawn are market followers. In pair 6 (pangasius and hilsa) and pair 10 (pangasius and long-whiskered catfish), there is bidirectional feedback from both markets. In these pairs, however, the prices of the captured species adjust faster than those of the cultured species. Of the nine pairs identified for market integration, the cultured species led in four cases, the captured species led in two cases, and there was a bidirectional relationship in three cases.

DISCUSSION

The adjustments to price changes following supply and demand shocks in the interrelated markets are mixed and can be characterized in three structures. The first is where the prices of both captured and cultured species are determined by each other; this occurs in three pairs: tilapia and hilsa, pangasius and hilsa, and pangasius and long-whiskered catfish. The implication in this structure is that growth in the cultured species would reduce or limit any substantial increase in prices of the captured species. Likewise, any shock in the captured species output would be reflected in the markets for the cultured species. This is the case of farmers and fishers operating in a competitive market. The second occurs where the cultured species determine the market prices for the captured species in the long run. This structure is the most common; it is identified for tilapia and prawn, tilapia and long-whiskered catfish, pangasius and swamp barb, and pangasius and prawn. The implication of this structure is that any shock, whether from the supply or the demand side, that leads to changes in the prices of the cultured species would be transmitted to the captured species markets, but not vice versa. As a result, increases in pangasius and tilapia output would limit price increases in the respective captured species markets, but not vice versa.

The third structure is where the captured species determine the market prices for the cultured species. This structure is identified for tilapia and swamp barb, as well as for pangasius and wallago. Here, shocks in the cultured species markets can hardly be felt in the captured species markets. However, shocks in the captured species markets are transmitted to the cultured market. This can be thought of as the case of partial linkage, with captured species trying to create a niche market in the long run. In these areas, fishers can gain a competitive edge over fish farmers. As the analysis is based on wholesale prices, the results are found on upstream price transmission. Although not tested, this is apparent because the fish are sold unprocessed at the wholesale market.

The main finding of market integration implies that the prices of captured and cultured species in the Bangladeshi fish market follow each other over time and are formed within the same market. Since the market share of cultured species is substantially larger than the market share of captured species, the implication is that the aquaculture supply growth reduces prices of both the cultured and the captured species and consequently decreases fishers' income in the short run. With regulated open-access, fishers may lose their incentives because of low prices, which ultimately cause the fall in captured fish supply in the short run. Since inland fishers leave, overexploitation is reduced, thereby increasing steady harvest in the long run. Fishers' income may increase or decrease, depending on how much catches increase and prices decrease. The profit of the active fishers, however, remains zero in the long run in regulated open-access, since fishers leave or enter until total revenue equals total costs.

Fisheries management can ensure that the gains from reduced overexploitation are not lost when reaching a new equilibrium. At the same time, it can ensure a further gain, through a reduction in the number of fishers. In developed countries, individual transferable quotas are becoming more commonly applied to achieve this purpose (Merayo et al. 2018; Nielsen, Smit, and Guillen 2012), although other fisheries management systems with different forms of regulated open-access and restricted open-access also continue to be used. Individual transferrable quotas generally generate rents, but the system also often reduces the number of vessels and employment, for example as reflected in the Danish case (Merayo et al. 2018). It may be difficult to change to a different management system. Doing so may cause unequal allocation of gains from common resources, an outcome that may not be desired, and may, like other quota systems, induce waste (Merayo et al. 2018).

In developing countries, however, the institutional framework of such a management system, including enforcement and control, may be weak. Transaction and enforcement costs often make it too expensive. Under such circumstances, community management may present a way to achieve further gains on a free market. In these systems, fishers cooperate on the exploitation of fish stocks and agree on the level of their activity, either in relation to the level of effort used in the fishery or in relation to the level of catches. Fishers commonly decide on a target for their activity; the target may correspond to the maximum economic yield, to maximization of employment in the long run, or to any other purpose. If some fishers are not willing to comply with the decisions agreed to by the community, social sanctions may result (Ostrom 2000). Hence, the system can theoretically ensure fulfillment of targets for the fish stocks commonly agreed on and simultaneously prevent or reduce overinvestment and overcapacity. However, lack of information may lead to a low quality of common decisions. Furthermore, it assumes that common decisions reflect the long-run perspective and do not maximize short-run gains. It also claims that all or most fishers accept the decisions of the group. Finally, the prerequisite for such a system to work is that it include everybody that fish on the stocks, which is often difficult when fishing villages are scattered. For inland fisheries in Bangladesh, community management may be advantageous when it is possible to define clear boundaries for exploitation of the fish stocks. For example, it is possible with stocks that stay in the same water systems: swamp barb, prawn, wallago, and long-whiskered catfish. Hilsa, however, is a species that migrates between freshwater river systems and marine areas, and hence it relies on public fisheries management.

CONCLUSIONS

This study examined market integration between captured and cultured fish in Bangladesh using monthly wholesale prices collected in different wholesale markets in Dhaka. Johansen's cointegration approach was used for the analysis. A bivariate analysis was conducted between two important species of cultured fish (tilapia and pangasius) and five species of captured fish (hilsa, swamp barb, prawn, wallago, and long-whiskered catfish). With the exception of tilapia and wallago, market integration was confirmed between all species. This indicates that there is significant market interaction between cultured and captured inland fisheries. The degree of market integration was, however, largely partial, except for pangasius and long-whiskered catfish where the LOP holds. The prices of the cultured and captured species are, therefore, partially linked and determined in a common seafood market system. Weak exogeneity tests provided mixed evidence on market leadership by revealing cases in which captured fish prices led the prices of cultured fish and vice versa. Cases of bidirectional market leadership were also revealed.

The large market share of cultured fish (70%) and the presence of market integration between cultured and captured fish except for tilapia and wallago have implications for producers, traders, consumers, and other actors in the value chain; that is, aquaculture supply growth reduces prices of captured fish, all things being equal (Anderson 1985). Reduced prices of cultured fish will also cause a reduction in the price for captured fish. As a result, fishers' income may, all other things equal, fall in the short run, which ultimately leads to fishers' exit from fishery. This consequently reduces overexploitation, overcapacity, and the number of fishers in the long run, given that we are in an initial situation of overexploitation. Hence, the result in the long run is that aquaculture supply growth leads to fewer fishers that catch more. A double gain in terms of aquaculture supply growth and increased catches in the captured species, therefore, may appear in the long run.

On top of the double gain, management of inland fisheries—to reduce overexploitation and the number of fishers—in developing countries can be obtained. Community management offers a way to achieve this when there is a lack of institutional fishery management or when the transaction costs are large. In this regard, the government should find ways to implement the regulations of the current fishery policies, and it also needs to initiate the regulations as early as possible in order to reduce the pressure on fisheries resources. Moreover, government can support poor fishers to develop alternative livelihoods through skill development, training, and credit support.

The main result implies that aquaculture supply growth can reduce the pressure on inland open-access or regulated open-access fish stocks when markets are integrated in Bangladesh. It may account for both inland open-access or regulated open-access fisheries and aquaculture growth in other countries like India, Myanmar, and Indonesia, as well as in other developing countries with large freshwater lake and river systems where growth of aquaculture is also expected to prevail. Hence, to achieve sustainable management of water bodies, sanctuaries, control of fishing effort, habitat restoration, and stocking, community planning and management institutions are needed.

This study provides new knowledge on interactions between inland fisheries and aquaculture in developing countries. However, there is ample scope for generating further knowledge with future analyses. First, the study departs from a weak knowledge on biological status of the inland fish stocks in Bangladesh. While this may be the situation in many and probably in most of the developing countries, more and better biological data can improve the reliability of the findings. Second, this study revealed only the existence and direction of fishers' gain, but did not identify its volume. Empirical bioeconomic models of inland fisheries can do that. Third, this study focused only on market interactions and did not consider other interactions. Such interactions may include cases of cultured fish escaping enclosures and competing with captured fish stocks for feed, or cases of inland fish entering the seasonally flooded cage areas and being captured there when the water levels fall. Bioeconomic modeling and studies of migration patterns can provide more knowledge on the biological and economic aspects of other interactions. Finally, this study departs realistically from the current situation of regulated open-access close to open-access in the inland fisheries in developing countries. If fisheries management is introduced, it will be important to obtain knowledge on interactions under simultaneous conditions of aquaculture growth and transition to inland fisheries management.

REFERENCES

Alam, M. F. 2011. "A Background Paper for Bangladesh Fisheries Value Chain Study." Accessed April 25, 2018. https://www.fao.org/valuechaininsmallscalefisheries/participatingcountries/Bangladesh/fr.

Amin, S. M. N., M. A. Rahman, G. C. Haldar, M. A. Mazid, and D. A. Milton. 2008. "Catch per Unit Effort, Exploitation Level and Production of Hilsa Shad in Bangladesh Waters." *Asian Fisheries Science* 21 (2): 175–87.

Anderson, J. L. 1985. "Market Interactions between Aquaculture and the Common-Property Commercial Fishery." *Marine Resource Economics* 2 (1): 1–24.

Ankamah-Yeboah, I., and J. Bronnmann. 2018. "Market Integration in the Crustaceans Market: Evidence from Germany." *Marine Policy* 87:72–77.

Ankamah-Yeboah, I., L. Ståhl, and M. Nielsen. 2017. "Market Integration of Cold and Warm Water Shrimp in Europe." *Marine Resource Economics* 32 (4): 371–90.

Asche, F., T. Bjørndal, and J. A. Young. 2001. "Market Interactions for Aquaculture Products." *Aquaculture Economics and Management* 5 (5–6): 303–18. https://doi.org/10.1080/13657300109380296.

Asche, F., D. V. Gordon, and R. Hannesson. 2004. "Tests for Market Integration and the Law of One Price: The Market for Whitefish in France." *Marine Resource Economics* 19 (2): 195–210.

Barten, A. P., and L. J. Bettendorf. 1989. "Price Formation of Fish: An application of an Inverse Demand System." *European Economic Review* 33:1509–25.

Bartley, D. M., G. J. De Graaf, J. Valbo-Jørgensen, and G. Marmulla. 2015. "Inland Capture Fisheries: Status and Data Issues." *Fisheries Management and Ecology* 22 (1): 71–77.

Bayramoglu, B. 2019. "Price Interactions between Wild and Farmed Products: Turkish Sea Bass and Sea Bream Markets." *Aquaculture Economics and Management* 23 (1): 111–32.

BER (Bangladesh Economic Review). 2018. "Sector-wise Fisheries Production." In *Annual Report*, 17th ed., 86–87. Tejgaon, Dhaka: Bangladesh Government Press.

Bjørndal, T., and J. Guillen. 2017. "Market Integration between Wild and Farmed Species in Spain." *Aquaculture Economics and Management* 21 (4): 433–51. https://doi.org/10.1080/13657305.2016.1214629.

Burton M. 1992. "The Demand for Wet Fish in Great Britain." *Marine Resource Economics* 7:57–66.

DAM (Department of Agricultural Marketing). 2017. "District-Wise Monthly Average Wholesale/Retail/Growers' Price of a Selected Commodity." Accessed January 21, 2017. http://dam.gov.bd/commodity_wise_report.

Dey, M. M., M. A. Rab, K. M. Jahan, A. Nisapa, A. Kumar, and M. Ahmed. 2005. "Food Safety Standards and Regulatory Measures: Implications for Selected Fish Exporting Asian Countries." *Aquaculture Economics and Management* 9 (1–2): 217–36.

Dickey, D. A., and W. A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74 (366a): 427–31.

———. 1981. "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root." *Econometrica: Journal of the Econometric Society* 49 (4): 1057–72.

DoF (Department of Fisheries). 2002–17. *Fisheries Statistical Yearbook of Bangladesh*. Fisheries Resources Survey System, Department of Fisheries, Ministry of Fisheries and Livestock.

———. 2016. *Annual Report*. Ministry of Fisheries and Livestock, Bangladesh. Accessed April 25, 2018. http://www.fisheries.gov.bd/site/view/annual_reports/Annual-Report.

———. 2018. "National Fish Week 2018 (18–24 July)." Ministry of Fisheries and Livestock, Bangladesh. Accessed February 22, 2019. https://drive.google.com/file/d/1VqaqIKlz-2XUStv7hXoqj2BvRVnyDKVT/view.

Emerson, J. 2007. "Cointegration Analysis and the Choice of Lag Length." *Applied Economics Letters* 14 (12): 881–85.

FAO (Food and Agricultural Organization of the United Nations). 2018. *The State of World Fisheries and Aquaculture 2018*. Rome: FAO.

———. 2019a. "Global Aquaculture Production 1950–2016." Accessed February 14, 2019. https://www.fao.org/fishery/statistics/global-aquaculture-production/query/%20en/en.

———. 2019b. "Global Capture Production 1950–2016." Accessed February 14, 2019. https://www.fao.org/fishery/statistics/global-capture-production/query/en.

———. 2019c. "National Aquaculture Sector Overview, Bangladesh." Accessed February 22, 2019. https://www.fao.org/fishery/countrysector/naso_bangladesh/en.

Fernando, C. H. 1994. "Zooplankton, Fish and Fisheries in Tropical Freshwaters." In *Studies on the Ecology of Tropical Zooplankton*, 105–23. Dordrecht: Springer.

Hasan, M. R. 2001. "Demand-Led Research and Management of Wild Freshwater Fish in Bangladesh." Support for Fisheries Education and Research (SUFER), Dhaka, Bangladesh, 76.

Hernandez, R., B. Belton, T. Reardon, C. Hu, X. Zhang, and A. Ahmed. 2018. "The 'Quiet Revolution' in the Aquaculture Value Chain in Bangladesh". *Aquaculture* 493:456–68.

Hjalmarsson, E., and P. Österholm. 2010. "Testing for Cointegration Using the Johansen Methodology When Variables Are Near-Integrated: Size Distortions and Partial Remedies." *Empirical Economics* 39 (1): 51–76.

Homans, F. R., and J. E. Wilen. 1997. "A Model of Regulated Open Access Resource Use." *Journal of Environmental Economics and Management* 32 (1): 1–21.

Hossain, M. A. R. 2014. "An Overview of Fisheries Sector of Bangladesh." *Research in Agriculture Livestock and Fisheries* 1 (1): 109–26.

Ioannidis, C., and D. Whitmarsh. 1987. "Price Formation in Fisheries." *Marine Policy* 11 (2): 143–45.

Islam, M. A., A. Al Asif, M. A. Samad, B. Sarker, M. Ahmed, A. Satter, and A. Hossain. 2017. "A Comparative Study on Fish Biodiversity with Conservation Measures of the Bhairabriver, Jessore, Bangladesh." *Asian Journal of Medical and Biological Research* 3 (3): 357–67.

Islam, M. S., H. Jahan, and A. A. Al-Amin. 2016. "Fisheries and Aquaculture Sectors in Bangladesh: An Overview of the Present Status, Challenges and Future Potential." *Journal of Fisheries and Aquaculture Research* 1 (1): 002–009.

Jaffry S., S. Pascoe, and C. Robinson. 1997. "Long Run Price Flexibilities for High Valued Species in the UK: A Co-Integration System Approach." *Applied Economics* 31:473–81.

Jensen, F., M. Nielsen, and R. Nielsen. 2014. "Increased Competition for Aquaculture from Fisheries: Does Improved Fisheries Management Limit Aquaculture Growth?" *Fisheries Research* 159:25–33.

Johansen, S. 1988. "Statistical Analysis of Co-integration Vectors." *Journal of Economic Dynamics and Control* 12 (2–3): 231–54.

Johansen, S., and K. Juselius. 1990. "Maximum Likelihood Estimation and Inference on Co-integration—With Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics* 52 (2): 169–210.

Juselius, K. 2006. *The Cointegrated VAR Model: Methodology and Applications*. New York: Oxford University Press.

Merayo, E., R. Nielsen, A. Hoff, and M. Nielsen. 2018. "Are Individual Transferable Quotas an Adequate Solution to Overfishing and Overcapacity? Evidence from Danish Fisheries." *Marine Policy* 87:167–76.

MoF (Ministry of Food). 2015. "National Food Policy Plan of Action and Country Investment Plan." Food Planning and Monitoring Unit, Government of the People's Republic of Bangladesh, Monitoring Report, 53.

Needham, S., and S. J. Funge-Smith. 2015. *The Consumption of Fish and Fish Products in the Asia-Pacific Region Based on Household Surveys*. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, RAP Publication 2015/12, 57–58.

Nielsen, M. 2005. "Linkages between Seafood Markets, Fisheries Management and Trade Liberalization: Theory and Applications." PhD thesis, University of Southern Denmark.

Nielsen, M., I. Ankamah-Yeboah, L. Staahl, and R. Nielsen. 2018. "Price Transmission in the Trans-Atlantic Northern Shrimp Value Chain." *Marine Policy* 93:71–79.

Nielsen, M., F. Jensen, J. Setälä, and J. Virtanen. 2011. "Causality in Demand: A Co-integrated Demand System for Trout in Germany." *Applied Economics* 43 (7): 797–809.

Nielsen, M., J. Setälä, J. Laitinen, K. Saarni, J. Virtanen, and A. Honkanen. 2007. "Market Integration of Farmed Trout in Germany." *Marine Resource Economics* 22 (2): 195–213.

Nielsen, M., J. Smit, and J. Guillen. 2009. "Market Integration of Fish in Europe." *Journal of Agricultural Economics* 60 (2): 367–85.

———. 2012. "Price Effects of Changing Quantities Supplied at the Integrated European Fish Market." *Marine Resource Economics* 27 (2): 165–80.

Norman-Lopez, A. 2009. "Competition between Different Farmed and Wild Species: The US Tilapia Market." *Marine Resource Economics* 24 (3): 237–51.

Norman-Lopez, A., and F. Asche. 2008. "Competition between Imported Tilapia and US Catfish in the US Market." *Marine Resource Economics* 23 (2): 199–214.

Ostrom, E. 2000. "Collective Action and the Evolution of Social Norms." *Journal of Economic Perspectives* 14 (3): 137–58.

Pincinato, R. B. M., and F. Asche. 2016. "Market Integration in Brazilian Shrimp Markets." *Aquaculture Economics and Management* 20 (4): 357–67. https://doi.org/10.1080/13657305.2016.1212124.

Ravallion, M. 1986. "Testing Market Integration." *American Journal of Agricultural Economics* 68 (1): 102–9.

Roos, N., M. A. Wahab, C. Chamnan, and S. H. Thilsted. 2007. "The Role of Fish in Food-Based Strategies to Combat Vitamin A and Mineral Deficiencies in Developing Countries." *Journal of Nutrition* 137 (4): 1106–9.

Sapkota, P., M. M. Dey, M. F. Alam, and K. Singh. 2015. "Price Transmission Relationships along the Seafood Value Chain in Bangladesh: Aquaculture and Capture Fisheries." *Aquaculture Economics and Management* 19 (1): 82–103.

Shamsuzzaman, M., X. Xiangmin, N. J. Tania, and M. Al-Mamun. 2017. "Constraints and Prospects of Sustainable Fisheries Management in Bangladesh." *Indian Journal of Geo-Marine Sciences* 46 (1): 7–15.

Stigler, G. J., and R. A. Sherwin. 1985. "The Extent of the Market." *Journal of Law and Economics* 28 (3): 555–85.

Toufique, K. A., S. N. Farook, and B. Belton. 2018. "Managing Fisheries for Food Security: Implications from Demand Analysis." *Marine Resource Economics* 33 (1): 61–85.

Valderrama, D., and J. L. Anderson. 2010. "Market Interactions between Aquaculture and Common-Property Fisheries: Recent Evidence from the Bristol Bay Sockeye Salmon Fishery in Alaska." *Journal of Environmental Economics and Management* 59 (2): 115–28.

Virtanen, J., J. Setälä, K. Saarni, and A. Honkanen. 2005. "Finnish Salmon Trout—Discriminated in the European Market." *Marine Resource Economics* 20 (1): 113–19.

WorldFish. 2019. "Bangladesh." Accessed July 18, 2019. https://www.worldfishcenter.org/country-pages/bangladesh.