AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Fish Price Volatility Dynamics in Bangladesh

Prokash Deb*

Graduate Research Assistant

Department of Agricultural Sciences

Texas State University, San Marcos, TX 78666

p_d123@txstate.edu

Madan M. Dey

Professor & Chair

Department of Agricultural Sciences

Texas State University, San Marcos, TX 78666

mmd120@txstate.edu

Prasanna Surathkal

Research Associate

Department of Agricultural Sciences

Texas State University, San Marcos, TX 78666

pras.kota@gmail.com

***Selected Paper prepared for presentation at the 2021 Agricultural & Applied
Economics Association Annual Meeting, Austin, TX, August 1 – August 3***

Copyright 2021 by Prokash deb, Madan M. Dey, Prasanna Surathkal. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

Fish Price Volatility Dynamics in Bangladesh

Abstract

Analyzing fish price volatility dynamics is essential to understand the impact of aquaculture growth in Bangladesh, a developing country where much of the animal source protein is obtained through fish consumption. In this article, we use both descriptive statistics and econometric modeling to understand the price volatility of four major aquaculture products at three important retail markets of Bangladesh as well as the efficiency of markets to adjust to a price shock. We utilize publicly available monthly retail fish price data of the Department of Agricultural Marketing (DAM) from January 2007 to December 2019. This period is characterized by a rapid transformation of the inland aquaculture sector in Bangladesh from largely low-intensity farming methods towards commercialization. Our results show that Bangladesh is experiencing lower fish price volatility during recent years for almost all the fish species analyzed in the study which may be the result of substantial growth in aquaculture production. The article also sheds light on the volatility persistence and finds almost all the markets are inefficiently adjusting to price shock which hints that there is more room for improving the functioning of fish markets in Bangladesh.

Keywords: fish, fisheries, aquaculture, price, volatility, market

1. Introduction

It is reasonable to assume that agricultural products tend to face higher economic uncertainty compared to industrial goods because of their dependency on nature and therefore it is difficult to predict and understand the price volatility pattern of agricultural products. Our understanding of fish price volatility is even shallower with respect to other agricultural goods as fish is a diverse commodity comprised of multiple species, forms, markets, and production technologies. In fact, significantly little attention has been given to study fish price volatility compared to cereals and meats (Dahl & Oglend, 2014; Gilbert & Morgan, 2010; Jacks et al., 2011; Ott, 2013; Wright, 2011) although fish provide approximately 20% of animal-source protein to over 3 billion people throughout the world and even more significant contribution in the developing countries which makes fish an essential component of diets (HLPE, 2014). A few studies have been conducted on fish price volatility dynamics so far focusing seafood and aquaculture industry (Asche et al., 2015; Bloznelis, 2016; Bose, 2010; Dahl, 2017; Dahl & Oglend, 2014; Oglend & Sikveland, 2008).

Generally, production and price uncertainty are the two main factors causing price fluctuation in the market. Production uncertainty can be dealt at an individual level (Dahl & Oglend, 2014) but price uncertainty is determined by the market where no individual producer has significant control over the price. Hence, fisheries industry is mostly affected by the production uncertainty as the world is experiencing a dramatic decline in capture fisheries since the last decade, and as a result fish and fish products from capture sources are facing high price fluctuation (Asche et al., 2015; Dahl, 2017). However, aquaculture technology has significant control over the production process and thus, the main concern is not production rather price uncertainty.

Therefore, it is essential to have a thorough investigation of fish price volatility dynamics for cultured fish species; especially for a country like Bangladesh which experiences a substantial increase (467% from 1984 to 2018) in fish production during last two decades because of intensifying aquaculture technology. FAO (2012) claimed that as aquaculture production continues to increase in the next decade, it will bring a significant impact on price formation leading to more volatility. This means FAO indicates aquaculture technology is more volatile than capture fisheries although aquaculture has higher control over the production process (Anderson, 2002; Asche, 2008; Dahl & Oglend, 2014). However, Tveterås et al. (2012) suggested that an

increase in aquaculture production may lead to lower price volatility and consumers can substitute high priced captured fish to lower-priced farmed fish.

However, because of the limited knowledge of fish price dynamics in Bangladesh, we do not know if the markets are experiencing uncertainty and greater price fluctuation because of the higher aquaculture growth or markets are more stable and less volatile as suggested by Tveterås et al. (2012). Therefore, the main focus of this article is to find out the change in fish price volatility dynamics subsequent to the substantial growth in aquaculture production in Bangladesh.

Another contribution of this study is the use of disaggregated time-series price data. In general, it is difficult to obtain disaggregated price data on fish in a developing country. However, in Bangladesh there is a publicly available, and hitherto underutilized, online database of prices. Named the “Commodity-wise Report”, this database is made available on the website of the Department of Agricultural Marketing (DAM) under the Ministry of Agriculture of the Government of the People’s Republic of Bangladesh. This valuable database provides time-series observations on the highest price, the lowest price, and the average price for different commodities and at different resolutions of geographic units (from the Divisional level to specific marketplace). Ours is one of the first studies to analyze this data, and it required a nontrivial manual effort to compile this data into a usable format.

The rest of the article is organized in the following way. First, we will provide a short overview aquaculture sector in Bangladesh followed by data source and testing basic time series properties. Then, the econometric modeling will be discussed where we apply the standard Generalized Autoregressive Conditional heteroskedasticity (GARCH) model to our time series to investigate the presence of heteroskedasticity and volatility clustering. This will be followed by results and discussions combining descriptive and econometrics results to understand the behavior of fish price fluctuation over time. In the end, we will provide the concluding remarks.

2. Fisheries and Aquaculture Sector in Bangladesh:

Bangladesh is experiencing a dramatic decline in capture fisheries. For instance, inland capture fisheries contribution decreased drastically from 40% to 28% of total fish production from 2006 to 2016 (Toufique et al., 2017). This is a major concern because fish is the major source of animal protein consumption for economically vulnerable people. On contrary, the demand for fish is

increasing at an exponential rate because of the higher population growth rate in the country. Therefore, intensifying aquaculture technology is the only feasible way to increase and maintain sustainable fish supply to fulfill the growing demand for fish. Thus, the country increased aquaculture production by 162.95% from 2004 to 2018 with an average growth of 5.26 percent and produced 4.276 million MT of fish in 2017-18 where the share of aquaculture was 56.24 percent (DOF, 2018). Also, the country is maintaining a consistent aquaculture growth of around 8.59 percent and expected to achieve total fish production of 4.552 million MT during 2021 projected by the present government as Vision-2021 (DOF, 2019). Therefore, the main objective for fisheries sub-sector of 8th five-year plan is to maintain sustainable growth in fish production for domestic consumption and export for optimum economic and social growth (Bangladesh Planning Commission, 2020). Figure 1 represents an overview of fish production trend in Bangladesh for last 36 years to illustrate the story.

Source: Yearbook of fisheries statistics of Bangladesh (DOF, 2019)

Total fish production in Bangladesh is dominated by the three Indian major carps (rohu, catla, mrigal), exotic carps (silver carp, grass carp, common carp, mirror carp, big head carp, black carp), and catfish (boal, air, silon, rita, pangas) groups alongside tilapia (*Oreochromis mossambicus*/O.

niloticus). Figure 2 illustrates species/group-wise fish production in Bangladesh. Rohu (*Labeo rohita*) forms a significant portion of major carp production while silver carp (*Hypophthalmichthys molitrix*) and pangas (*Pangasius hypophthalmus*) dominate the exotic carp and catfish groups, respectively.

Source: Yearbook of fisheries statistics of Bangladesh (various issues)

A salient feature of Figure 2 is the spectacular increase in the production of tilapia and pangas in recent years. Farming of pangasius, and to a lesser extent that of tilapia, takes place in highly intensive systems involving the use of floating feeds, higher stocking density, and other such intensive operations. Belton et al. (2011) note that homestead/subsistence aquaculture in Bangladesh produced about 399,000 tons of fish from 265,000 ha, semi-intensive carp farming production was about 390,000 tons from 110,000 ha, whereas intensive farming of pangas and tilapia produced about 395,000 tons from just 15,000 ha. Increased supply would exert downward pressure on relative prices. It is also plausible to expect lower variability of fish prices with an increase in aquaculture production, especially considering the impact on fish demand created by faltering capture fisheries production in Bangladesh.

Furthermore, exotic carp are also mostly originated from aquaculture. However, capture fishery was the main source of major carps but as capture fisheries started to decline in recent years, major

carps production also shifted from capture to culture. Thus, we can see a production shock between 2013 to 2016 where producers were shifting from their reliance on capture fish production to intensifying aquaculture technology to produce major carps. Moreover, the pond culture is dominated by carp production, which accounts for 59% of total fish production in ponds, with the other two farmed species being tilapia and pangas (Belton et al., 2011). In figure 2 we can see catfish production plummeted from 360.745 thousand MT in 2013 to only 81.536 thousand MT in 2014. This is because prior to 2014 Department of fisheries (DOF) merged pangas with other catfish production. However, as the production of pangas under aquaculture started to increase at a substantially higher rate compared to other catfish which are produced from capture sources, DOF separated pangas fish species from the catfish group.

Moreover, although we may assume that fish farming in Bangladesh is subsistence-oriented, 75% of fish producing households directly or indirectly sell their production (Hernandez et al., 2018). Therefore, lower fish price volatility will bring two-fold benefits. First, the stability of price reduces the market risk which encourages more producers to enter the market and intensify the production which will increase employment opportunity along the value chain. Second, this increase in production will eventually reduce the fish price and increase the availability of fish to poor households with consistent supply which will bolster the food and nutritional security. Therefore, the country will be enormously benefited from higher aquaculture growth by which fish become more accessible to all people regardless of groups and classes. Hence, it is very important to answer the question: has higher aquaculture growth reduced fish price volatility in Bangladesh?

3. Materials and Methodology

3.1 Data:

We utilize publicly available fish price data collected from the “Commodity-wise Report” database of DAM. We compile monthly retail price data for January 2007 to December 2019 period for four major aquaculture fish species: silver carp, tilapia, pangas, and locally produced rohu. This time frame covers the transition period of fish production in Bangladesh from capture fisheries to culture fisheries. Price data is collected for three major aquaculture productive geographical locations (divisions) of the country: Dhaka, Khulna, and Rajshahi. These divisions are divided into small administrative districts and hence, we make the average of districts level market price within

the same division for a true reflection of average division price. The default currency of Bangladesh (taka) and weight as kilograms (kg) are used throughout the study.

3.2 Testing Basic Time Series Properties:

One of the fundamental and most important issues of modeling time series data is stationarity. A time series is said to be stationary if its mean (μ) and variance (σ^2) are constant over time. By nature, most of the time series price data are non-stationary at level. However, it is very important to work with stationary data because time series modeling with non-stationary data (having unit root) may cause misleading interpretations (Granger & Newbold, 1974; Hill et al., 2011).

The most common way to make the data stationary is by converting the price as log returns. Let R_t defined as the log returns price whereas, R_t can be written as:

$$R_t = \log(P_t) - \log(P_{t-1})$$

Here, P_t is the price of a fish product at a geographical market at time t and P_{t-1} is the price in the previous period, for example, the previous month, day, or year. The expected value of log returns generally very close to zero and time-varying variance. Generally, the log returns are driven from a normal distribution which has zero mean and variance changes over time, $R_t \sim N(0, \sigma^2)$. Although these assumptions of zero mean and normal distribution are not necessary to follow, in this article, we assume these conditions to be true and do further statistical tests to accept or reject the null hypothesis.

Moreover, there are many statistical tests to determine whether a time series is stationary or nonstationary. The most widely used test is Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1981). There are three varieties of ADF test: ADF with no constant and no trend, with constant but no trend, with constant and trend. The result varies based on three conditions and thus, we need to be very cautious of selecting the suitable condition by plotting the data series before running ADF test. The null hypothesis (H_0) of ADF test: there is unit root in the data series, whereas the alternative hypothesis (H_1): the data series is stationary.

Another widely use stationarity test is Kwiatkowski-Phillips-Schmidt-Shin test (KPSS) (Kwiatkowski et al., 1992). We use this test because the null hypothesis testing for KPSS is the

opposite of ADF test. The null hypothesis (H_0) of KPSS: the data series is stationary while the alternative hypothesis (H_1): the data series is non-stationary.

Additionally, before conducting unit root test, we need to specify optimal lag selection for all the price series. The most common method of selecting optimal lag is based on Akaike Information Criterion (AIC), Schwarz Criterion (SC) which is also known as Bayes Information Criterion (BIC), and Hannan-Quinn Information Criterion (HQIC). We use minimum HQIC value for optimum lag selection for unit root test. In all other cases, minimum AIC will be used to select the optimum lag order.

3.3 Econometric Model to Determine Volatility:

A thorough descriptive statistical is conducted at the beginning to know the distribution pattern such as mean, minimum and maximum value, skewness, and kurtosis of the stationary data series (log return data). Then, Jarque and Bera (JB) test is used to determine the normality of the data series (Jarque & Bera, 1987) where the null hypothesis (H_0): the data series is normally distributed. Moreover, Ljung-Box test is performed both on log returns (Q) and squared log returns (Q^2) to determine serial correlation. The null hypothesis (H_0) of Ljung-Box test: the data series is independently distributed (no autocorrelation), whereas the alternative hypothesis (H_1): the data series has serial correlation.

After the autocorrelation test, we examine the Autoregressive Conditional Heteroskedasticity (ARCH) property of data series. ARCH represents the time-varying variance which is known as heteroskedasticity that depends on lagged effects (serial correlation) which was first introduced by Engle (1982) to determine the ARCH effect on United Kingdom Inflation. The most popular way to determine the presence of the ARCH effect is Lagrange multiplier (LM) test. For this, we need to determine the mean equation of the model and then regress the model with constant. After that, we estimate the residuals ($\hat{e}_t$) and obtain the residual squares $\hat{e}_t^2$. Finally, to find the ARCH for first order, we regress the residual square $\hat{e}_t^2$ on the lagged residual square $\hat{e}_{t-1}^2$.

$$y_t = \phi + e_t \dots (\text{base model})$$

$$\hat{e}_t^2 = \alpha_0 + \alpha_1 \hat{e}_{t-1}^2 + y_t$$

The conditional distribution of the error (e_t) in most cases is normal while the error of unconditional distribution may not be normal (Hill et al., 2011). The null hypothesis (H_0) of ARCH-LM test: there is no conditional heteroskedasticity in the data series whereas, the alternative hypothesis (H_1): there is presence of conditional heteroskedasticity. Thus, if there is no ARCH effect then α_1 will be zero and the goodness of fit (R^2) will be very low. However, if there is ARCH effect then the magnitude of $\hat{e}_t^2$ will be dependent on its lagged values and the R^2 will be relatively higher (Hill et al., 2011).

Generally, for most of the time series data, we may not find the ARCH effect at first lag. So, we use ARCH(q) model where q represents the number of lag and the equation can be written as,

$$h_t = \alpha_0 + \alpha_1 \hat{e}_{t-1}^2 + \alpha_2 \hat{e}_{t-2}^2 + \alpha_3 \hat{e}_{t-3}^2 + \dots + \alpha_q \hat{e}_{t-q}^2 \dots (1)$$

Here, h_t is the estimated residual square.

However, the main problem with the ARCH(q) model is that it loses accuracy for large lag (q). Hence, if there is evidence of ARCH effect then we will further utilize the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model to estimate the volatility more accurately. This method was introduced by Bollerslev (1986) where he adds the previous period volatility with the ARCH model to predict future volatility more accurately. The elaboration of the GARCH model is given bellow by rewriting the equation 1 as,

$$h_t = \alpha_0 + \alpha_1 \hat{e}_{t-1}^2 + \beta_1 \alpha_1 \hat{e}_{t-2}^2 + \beta_1^2 \alpha_1 \hat{e}_{t-3}^2 + \beta_1^3 \alpha_1 \hat{e}_{t-4}^2 + \dots \dots (2)$$

Here, a geometric lag structure is imposed on the lagged coefficients of the form; $\alpha_s = \alpha_1 \beta_1^{s-1}$

If we add $\beta_1 \alpha_0$ in equation 2 then,

$$h_t + \beta_1 \alpha_0 = \alpha_0 + \alpha_1 \hat{e}_{t-1}^2 + \beta_1 \alpha_0 + \beta_1 \alpha_1 \hat{e}_{t-2}^2 + \beta_1^2 \alpha_1 \hat{e}_{t-3}^2 + \beta_1^3 \alpha_1 \hat{e}_{t-4}^2 + \dots$$

$$h_t = (\alpha_0 - \beta_1 \alpha_0) + \alpha_1 \hat{e}_{t-1}^2 + \beta_1 (\alpha_0 + \alpha_1 \hat{e}_{t-2}^2 + \beta_1^2 \alpha_1 \hat{e}_{t-3}^2 + \dots)$$

$$h_t = \gamma + \alpha_1 \hat{e}_{t-1}^2 + \beta_1 h_{t-1}$$

Thus, a simplified GARCH(p,q) model can be written as,

$$\sigma_t^2 = \omega + \sum_{i=1}^p \alpha_i R_{t-i}^2 + \sum_{j=1}^q \beta_j \sigma_{t-j}^2$$

Here, β_j is a positive constant.

This is a very popular formula to determine volatility because of its accuracy with a better fit even with fewer parameters than ARCH model (Molnár, 2016). Even though many specifications of the GARCH model have been developed over the years, most surprisingly still now, GARCH (1,1) yields a better result than other GARCH models in most of the cases (Kat & Heynen, 1994; Lim & Sek, 2013). Thus, we use the GARCH (1,1) model to determine the volatility clustering in the data series. The most common way to write the GARCH (1,1) model is:

$$\sigma_t^2 = \omega + \alpha R_{t-1}^2 + \beta \sigma_{t-1}^2$$

4. Results and Discussions

Table 1 represents the stationarity test at level and log returns of four selected fish species in three different geographical locations (divisions). The ADF test shows all the fish species are stationary at level except pangas at Khulna market. However, the null hypothesis of unit root for the log returns series are rejected at 1% significance level regardless of species and markets. Moreover, the KPSS test shows all the price series are non-stationary at level while the log returns are stationary. The KPSS results are very similar to ADF test except the pangas at Khulna market. The ADF test sometimes gives misleading result when the test statistics is very close to the critical value which may cause the pangas price stationary at 10% level of significance but non-stationary for KPSS test. Thus, we consider all the price series non-stationary at level and stationary at log returns.

Figures 3 through 6 represent price (taka/kg) and squared log return series for the selected fish species. We provide graphs of only Dhaka division market prices as other markets show similar price behavior. Dhaka is also the capital and largest retail market in the country. The level price (taka/kg) and squared log returns series are represented as blue and orange lines, respectively. Overall, from the figures, we can see that there is an increasing trend of fish price in the early years but showing a drifting pattern rather than trending upward in recent years. This happens not only for a single fish species in Dhaka market rather in all markets regardless of species.

Table 1: Stationarity test at level and log return series of selected fish species

Division & Species	ADF (level)	ADF (1 st difference)	KPSS (level)	KPSS (1 st difference)
Dhaka				
Silver carp	-2.469	-3.905***	0.824***	0.0726
Rohu	-1.487	-5.829***	0.339***	0.0326
Tilapia	-2.609	-13.360***	1.28***	0.0203
Pangas	-2.626	-10.731***	0.825***	0.0426
Rajshahi				
Silver carp	-2.381	-7.569***	0.606***	0.0258
Rohu	-3.140	-12.785***	0.696***	0.0286
Tilapia	-2.702	-11.257***	1.18***	0.0217
Pangas	-2.264	-10.682***	0.677***	0.0197
Khulna				
Silver carp	-3.085	-8.177***	0.579***	0.05
Rohu	-2.862	-12.866***	0.987***	0.0185
Tilapia	-2.073	-6.933***	0.3***	0.0296
Pangas	-3.260*	-12.212***	0.635***	0.0282

Notes: ***, **, and * represent rejecting null hypothesis at 1%, 5% and 10% level of significance, respectively.

Moreover, the squared log returns series indicate lower price fluctuation during the last five years compared to earlier years, for almost all species and markets. This means Bangladesh is experiencing significantly lower price volatility after 2013. In fact, there is substantial evidence of higher commodity price fluctuation in the early periods (pre-2013 periods) all over the world because of shocks in production, increase in energy and fertilizer prices, restrictive trade policies, lower global inventories, higher oil prices, structural change in global food demand, inelastic markets, etc. (Abbott et al., 2011; Headey & Fan, 2008; Rezitis & Sassi, 2013; Schnepf, 2008; Trostle, 2008; Wright, 2009, 2011). Also, higher food price volatility occurred during the early 2000s because of larger liquidity shock by adopting expansionary monetary policy by all major countries to bring stability in the economic sectors to tackle the financial crisis, higher unemployment, economic contraction, and deflationary tendencies (Belke et al., 2013).

Notes: blue and orange lines represent level price (taka/kg) and square log returns price, respectively.

Nevertheless, lower price fluctuation of any agricultural product can be the result of two main reasons. First, market becomes well-efficient where there is a sufficient flow of information along the value chain. Second, consistent growth in production which fulfills the increasing demand and smooth the supply curve. In Bangladesh, we have not seen a significant structural and regulatory change in the fish market which may influence the price. However, some minor changes are occurring, for instance, producers nowadays are actively involved in fish marketing by approaching wholesalers at the higher secondary market or directly selling fish which is mostly because of the increasing production in pond polyculture (Sapkota et al., 2015). But this reason solely cannot stabilize the fish price in the retail market for such a long time.

Furthermore, among the selected fish species, silver carp, tilapia, and pangas production are almost entirely driven by aquaculture. On the other hand, a large share of rohu production was driven from capture sources in earlier periods but in recent years aquaculture dominates the production of rohu because of the rapid decline in capture fisheries. While comparing to other fish species, we can not find a substantial change in volatility pattern of rohu since last decade apart from a minor decline in price fluctuation in last two years. This implies aquaculture is efficiently smoothing the long run supply curve although there is a supply deficit created by decline in capture fisheries. However, there is a significant price shock of rohu between 2014 to 2016 in Dhaka market which may be the reason of production shock of major carp during that time (figure 2). This finding may hint that lower fish price fluctuation may be the result of higher aquaculture production which helps to stabilize the retail fish price.

In fact, lower volatility because of higher production from aquaculture is investigated by many researchers. For instance, Asche et al. (2015) investigated seafood price volatility regimes along technology, species, and product form dimensions. They noticed significant differences in volatility between aquaculture products and wild capture products. In general, lower volatility was found in aquaculture compared to capture products. While comparing aquaculture volatility with other commodities, Dahl & Oglend (2014) found aquaculture products are among the least volatile commodity along with gold, feeder cattle, fishmeal, and chicken while fish products such as Tuna, wild catch fish, pelagic (other than tuna) are found to be highly volatile. Hence, Dahl (2017) stated that lower price volatility of aquaculture products may be the result of better control over production which smoothes the supply and manages price risk. He even predicted that in the near future we may see substantially higher market share of seafood by aquaculture because of its well-organized and efficient production technique.

Table 2: Descriptive statistics

Division & Species	Mean (%)	Volatility	Minimum value	Maximum value	Skewness	Kurtosis
Dhaka						
Silver carp	5.049	0.145	-0.109	0.153	0.153	1.269
Rohu	4.343	0.195	-0.237	0.271	-0.063	5.710
Tilapia	3.897	0.137	-0.118	0.141	-0.217	1.092
Pangas	5.573	0.136	-0.149	0.121	-0.043	2.316
Rajshahi						
Silver carp	6.010	0.143	-0.131	0.171	0.160	2.147
Rohu	4.968	0.148	-0.214	0.151	-0.805	6.491
Tilapia	3.375	0.140	-0.126	0.137	0.106	1.681
Pangas	5.401	0.210	-0.327	0.250	-1.008	8.929
Khulna						
Silver carp	5.609	0.168	-0.205	0.216	0.319	4.921
Rohu	4.110	0.144	-0.154	0.203	0.154	4.645
Tilapia	4.156	0.167	-0.224	0.209	0.354	5.944
Pangas	5.598	0.168	-0.133	0.165	0.317	1.320

Notes: mean is annualized percentage and volatility is the yearly mean of standard deviation of log returns series.

Table 2 represents the descriptive statistics of the log returns price series which includes mean, volatility, minimum value, maximum value, skewness, and kurtosis. The mean represents annualized percentage and the volatility as the yearly mean of the standard deviation of log returns series. Overall, Dhaka market represents the lowest mean value for silver carp and tilapia. On the

other hand, Khulna and Rajshahi markets show the lowest mean value for rohu and pangas, respectively.

Generally, in terms of volatility, Dhaka market for all the fish species (except rohu) shows very low price fluctuation. This is because Dhaka market is the center and capital of the country and thus, gets supply from all the major markets. This consistency and higher supply help to reduce the price movements. However, rohu fish price in Dhaka market was highly fluctuating during the first six months of 2015 which makes aggregate volatility higher. Additionally, among all the fish species, rohu fish in all the markets shows very low skewness (negative except Khulna) and kurtosis above 4 which represents a leptokurtic distribution.

Table 3 represents Jarque-Bera (JB) test for normality, Ljung-Box portmanteau test for autocorrelation, and ARCH-LM test to determine the ARCH effect in the data series. The JB test result rejects the null hypothesis of normality for all the price series at 1% level of significance which means the data series are driven from a non-Gaussian distribution. This is not a concern because there is a plethora of real-world market level price data drawn from non-normal distributions (Hill et al., 2011). The Ljung-Box portmanteau test is done for both log returns (Q) and square log returns series (Q^2). The test statistics for both log returns and squared log returns reject the null hypothesis of no autocorrelation for all the series except tilapia at Rajshahi market. Similarly, the ARCH-LM test rejects the null hypothesis of homoscedasticity at 1% level of significance for all the price series except tilapia in Dhaka and Rajshahi markets. Hence, the results of ARCH-LM test suggest that the GARCH model can be used to determine the dynamics of volatility clustering for the price series.

Table 4 provides the results of standard GARCH model. A t-distribution is considered in this case as data is driven from a non-normal distribution. The best mean model which is ARMA (p,q) is selected based on a combination of lowest AIC criteria, partial autocorrelation (PACF), and autocorrelation (ACF) function from the squared residual of the series (Bollerslev, 1986). The mean model is not included in the table because it varies from AR (0) to AR (4) and MA (0) to MA (5) among different series. The estimates of GARCH (1,1) model yield some general output in almost all cases. For instance, the constant parameter ω is significantly small (very close to zero) and the addition of ARCH and GARCH coefficient ($\alpha + \beta$) is very close to but smaller than 1 whereas most of the weight is on GARCH coefficient (β) (Hill et al., 2011; Molnár, 2016).

Table 3: Normality, autocorrelation, ARCH test

Division and Species	JB test	Ljung-Box test (Q)	Ljung-Box test (Q ²)	ARCH (chi2)
Dhaka				
Silver carp	11.956***	39.653***	17.233***	16.75***
Rohu	219.17***	70.97***	126.15***	64.940***
Tilapia	9.7325***	14.581**	2.763*	1.091
Pangas	36.818***	8.980**	19.219***	18.510***
Rajshahi				
Silver carp	32.364***	27.255***	5.772**	12.786***
Rohu	299.74***	25.228***	24.288***	11.242***
Tilapia	19.898***	1.475	2.28	2.531
Pangas	559.79***	4.007**	19.04***	17.113***
Khulna				
Silver carp	165.72***	14.155*	20.557***	50.043***
Rohu	146.06***	16.942**	17.719***	40.800***
Tilapia	240.55***	27.656***	56.149***	20.602***
Pangas	14.895***	17.305**	36.745***	9.094***

Notes: ***, **, and * represent rejecting null hypothesis at 1%, 5% and 10% level of significance, respectively.

For more than half of the price series, the ARCH effect (α) is significant which means there is evidence of unexpected shocks. On the other hand, GARCH effect (β) which shows conditional volatility is significant for all the series (except pangas at Dhaka market). This indicates that future price depends on the previous price and volatility. We also conducted the autocorrelation test on the residuals to identify the model goodness. The Ljung-Box test of autocorrelation of the model residuals does not reject the null hypothesis of no serial correlations. In all the cases, the p-value is higher than 10% level of significance (except silver carp and rohu in Khulna market) which indicates the goodness of the models.

Moreover, the summation of ARCH (α) and GARCH (β) coefficient in GARCH (1,1) model measures the degree of volatility persistence at the market. The volatility persistence on the other hand measures the efficiency of the market as an efficient market can correct any shock within a short period rather than dissipating it (Oglend & Sikveland, 2008). In our model, volatility persistence varies from 0.8588 to 0.9989 among species and markets. In general, Dhaka market shows slightly lower volatility persistence which means Dhaka market displays a relatively larger degree of efficiency. This result is predictable because as described earlier that Dhaka market collects supply from all over the country.

Table 4: Standard GARCH test

Division and Species	Constant (ω)	ARCH (α)	GARCH (β)	Log (L)	AIC	BIC
Dhaka						
Silver carp	0.0000 (0.0000)	0.1096 (0.0813)	0.8786*** (0.0678)	291.9659	-3.6641	-3.5070
Rohu	0.0003 (0.0001)	0.4714*** (0.1557)	0.3874*** (0.1249)	282.4567	-3.5027	-3.2862
Tilapia	0.0000 (0.0000)	0.1010 (0.0928)	0.8786*** (0.0991)	298.3046	-3.7072	-3.4912
Pangas	0.0003 (0.0002)	0.6992** (0.2885)	0.2243 (0.1922)	308.6024	-3.8787	-3.7217
Rajshahi						
Silver carp	0.0000 (0.0000)	0.3123** (0.1244)	0.6866*** (0.0801)	309.2802	-3.8617	-3.6653
Rohu	0.0000 (0.0000)	0.0171 (0.0135)	0.9705*** (0.0135)	314.966	-3.9350	-3.7387
Tilapia	0.0000 (0.0000)	0.0801** (0.0398)	0.9187*** (0.0170)	299.4069	-3.7343	-3.5379
Pangas	0.0003 (0.0001)	0.4832** (0.2121)	0.5157*** (0.1312)	273.614	-3.4402	-3.3027
Khulna						
Silver carp	0.0000 (0.0000)	0.2898*** (0.0969)	0.7091*** (0.0879)	310.0949	-3.8980	-3.7409
Rohu	0.0000 (0.0000)	0.0138 (0.0155)	0.9780*** (0.0147)	304.2529	-3.7968	-3.6005
Tilapia	0.0000 (0.0000)	0.0937 (0.0611)	0.9052*** (0.0341)	306.3357	-3.8237	-3.6273
Pangas	0.0000 (0.00000)	0.2701 (0.1827)	0.7288*** (0.1970)	278.5125	-3.4905	-3.3334

Notes: ***, **, and * represent rejecting the null hypothesis at 1%, 5% and 10% level of significance, respectively. Standard error inside the parenthesis. Log (L) represents log likelihood.

Silver carp, tilapia, and pangas are mostly consumed by people living below the poverty line and thus they are largely sold in the rural markets. Hence, rigid pricing may be the most viable reason for these three fish species to show lower degree of market efficiency. Rigid pricing occurs when there is higher cost associated with revising prices mostly because of limited flow of information which is a typical characteristic of rural markets in developing countries. Also, the price impact of new market information will be undermined because of higher price rigidity (Oglend et al., 2021).

On contrary, rohu not only has cultural significance but also consumed by all people regardless of groups and classes. Moreover, the country is experiencing tremendous growth in pond polyculture

where 59% is constituted of carp production (Belton et al., 2014; Sapkota et al., 2015). As carp production is mostly dominated by rohu (DOF, 2018), the increase in carp production helps to maintain consistency of rohu supply which stabilizes the price while lowering volatility persistence.

It is commonly observed for a developing country that agricultural commodity markets are less efficient and more volatile than developed countries where markets tend to be well-efficient. For instance, Oglend & Sikveland (2008) found the volatility persistence for the Norwegian salmon industry was 0.81 that indicates an efficient market which is even better than some agricultural goods such as corn (0.94), soybeans (0.88), and menhaden (0.38) (Buguk et al., 2003). This lower volatility in the Norwegian salmon industry is mostly because of substantial growth in salmon farming and sold more than double (from 298 to 625 thousand metric tons) salmon from 1996 to 2006 (Oglend & Sikveland, 2008).

5. Conclusion

In this article, we focus on price uncertainty rather than production uncertainty as aquaculture technology has significant control over the production process. In Bangladesh, price risk has not received much attention, as most of the research is focused on the production and consumption aspect of aquaculture. This is despite the importance of price uncertainty for Bangladesh- where aquaculture is the major source of fish intended for human consumption, and fish is the most frequently consumed animal sourced staple food. Hence, we have utilized fish price data collected from the Department of Agricultural Marketing (DAM) of Bangladesh from January 2007 to December 2019 of four mostly farmed fish species; silver carp, tilapia, pangas, and rohu. We consider the retail price because consumers only purchase fish from the retail markets.

Our analysis finds that all the price series have unit root at level but stationary at log return. The log return series are driven from non-Gaussian distribution, and skewness and kurtosis vary widely across species and locations. The null hypothesis of no serial correlation in the residuals of log returns and squared log returns of all the fish price series is rejected except for tilapia at Rajshahi market. Moreover, almost all the species showed ARCH-LM effect except tilapia in Dhaka and Rajshahi markets. ARIMA model or the mean model for GARCH (1,1) also varies across different species and divisions. Almost all the fish species exhibit the GARCH effect as the GARCH

coefficient (β) is significant which means we can predict future volatility using the current volatility in the market.

The main two findings of this article are as follows. First, Bangladesh experienced an increasing fish price trend and higher volatility in the early years. In fact, the whole world had experienced higher food price volatility during the early 2000s due to a variety of reasons, but lower fish production might be one of the main reasons for unstable fish prices in Bangladesh. Hence, the price fluctuations become significantly low in recent years as the country experienced substantial growth in total fish production through intensifying aquaculture technology. This means, higher aquaculture production may contribute to lower fish price volatility. Among all the fish species, rohu showed the lowest price movement in Dhaka market as this is the capital and largest market in the country.

Second, the standard GARCH model reveals that for almost all the fish species GARCH coefficient is significant and most of the weight is also on GARCH coefficient (β). The volatility persistence showed that the selected markets are inefficient to manage a price shock in the short run. However, compared to other fish species, rohu in Dhaka market showed lower volatility persistence which indicates a higher degree of efficiency.

Moreover, the implication of the study goes beyond Bangladesh. Because of the decline in world capture fisheries, most of the production is driven from culture fisheries and hence, the world aquaculture contribution to global fish production increased significantly from 25.7% in 2000 to 46.0% in 2018 (FAO, 2020). Therefore, almost all the developing countries with high per capita fish consumption also experiencing enormous aquaculture growth all over the world. For instance, after China and India, the largest aquaculture fish producers are as followed: Indonesia (3rd), Viet Nam (4th), Bangladesh (5th), Egypt (6th), Myanmar (9th), Thailand (10th), Philippines (11th), and Brazil (13th) (FAO, 2020). Hence, the increase in aquaculture production in these higher per capita fish consuming countries should also affect the price dynamics in the domestic markets like Bangladesh.

6. Notes:

1. Almost all the data series compiled from the DAM have missing values between 10% to 15%. To impute the missing value, we use the Kalman filter which operates based on the state-space model. To elaborate, let us consider a simple model where $\mu_t = \alpha_t$. Here, α_t is unpredictable with no seasonality and normally distributed. The model can be written as:

$$y_t = p_{\alpha_t} + \varepsilon_t \dots (3)$$

$$\alpha_{t+1} = z\alpha_t + n_t \dots (4)$$

Here, for both equations, ε_t and n_t are normally distributed with mean 0 and variance σ^2 . Both ε_t and n_t are mutually independent for $t = 1, \dots, n$ and also independent from α_t . Moreover, y_t is observed series with missing value while α_t is totally unobserved. The third equation is called a measurement equation where observed value is related to unobserved states and the fourth equation called the transition equation where the unobserved states evolved over time. Typically, the Kalman filter uses the current observation y_t for the best estimate of α_{t+1} as follows:

$$\alpha_{t+1} = z\alpha_t + K_t(y_t - p_{\alpha_t})$$

Here, K_t is Kalman gain (Durbin & Koopman, 2012; Jalles, 2009).

2. The Akaike Information Criterion is given by:

$$AIC = \ln\left(\frac{SSE}{T}\right) + \frac{2k}{T}$$

the Bayes Information Criterion can be written as,

$$BIC = \ln\left(\frac{SSE}{T}\right) + \frac{k \ln(T)}{T}$$

And Hannan-Quinn Information Criterion can be written as,

$$HQ = \ln\left(\frac{SSE}{T}\right) + \frac{2k}{T} \ln(\ln T)$$

In all cases the first term, $\ln\left(\frac{SSE}{T}\right)$ become smaller as more variables (lags) are added which reduces the SSE; however, the second term becomes larger because K increases. As $\frac{k \ln(T)}{T}$ is

greater than $\frac{2k}{T}$, adding extra variable (lag) increases BIC more than AIC and thus, generally, AIC is smaller than BIC (Hill et al., 2011).

3. Jarque and Bera (JB) can be written as,

$$JB = N \left[\frac{(\sqrt{b_1})^2}{6} + \frac{(b_2 - 3)^2}{24} \right]$$

Here, N is the sample size, b_1 is the sample skewness, b_2 is sample kurtosis.

4. Ljung-Box test formula can be written as,

$$Q = n(n+2) \sum_{k=1}^h \frac{\hat{\rho}_k^2}{n-k}$$

Here, n is the sample size, ρ_k the sample autocorrelation with lag k, and h is the number of tested lags.

7. References:

- Abbott, P. C., Hurt, C., & Tyner, W. E. (2011). What's driving food prices in 2011? *Farm Foundation*.
- Anderson, J. L. (2002). Aquaculture and the future: why fisheries economists should care. *Marine Resource Economics*, 17(2), 133–151. <https://doi.org/10.1086/mre.17.2.42629357>
- Asche, F. (2008). Farming the sea. *Marine Resource Economics*, 23(4), 507–527.
- Asche, F., Dahl, R. E., & Steen, M. (2015). Price volatility in seafood markets: farmed vs. Wild fish. *Aquaculture Economics and Management*, 19(3), 316–335. <https://doi.org/10.1080/13657305.2015.1057879>
- Bangladesh Planning Commission (2020). 8th Five Year Plan (July 2020 – June 2025). General Economics Devision (GED), Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.
- Belke, A., Bordon, I. G., & Volz, U. (2013). Effects of global liquidity on commodity and food prices. *World Development*, 44(July 2012), 31–43. <https://doi.org/10.1016/j.worlddev.2012.12.009>
- Belton, B., Karim, M., Thilsted, S., Murshed-E-Jahan, K., Collis, W., & Phillips, M. (2011). Review of aquaculture and fish consumption in Bangladesh. *The WorldFish Center*. <http://ideas.repec.org/b/wfi/wfbook/39574.html>

- Belton, B., van Asseldonk, I. J. M., & Thilsted, S. H. (2014). Faltering fisheries and ascendant aquaculture: implications for food and nutrition security in Bangladesh. *Food Policy*, 44, 77–87. <https://doi.org/10.1016/j.foodpol.2013.11.003>
- Bloznelis, D. (2016). Salmon price volatility : a weight-class-specific multivariate approach. *Aquaculture Economics & Management*, 20(1), 24–53. <https://doi.org/10.1080/13657305.2016.1124936>
- Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, 31, 307–327. <https://doi.org/10.1109/TNN.2007.902962>
- Bose, S. (2010). Price volatility of south-east fishery ' s quota species : an empirical analysis. *International Economic Journal*, 18(3), 283–297. <https://doi.org/10.1080/1016873042000269966>
- Buguk, C., Hudson, D., & Hanson, T. (2003). Price volatility spillover in agricultural markets: an examination of u.s. catfish markets. *Journal of Agricultural and Resource Economics*, 28(1), 86–99.
- Dahl, R. E.. (2017). A study on price volatility in the aquaculture market using value-at-Risk (VaR). *Aquaculture Economics and Management*, 21(1), 125–143. <https://doi.org/10.1080/13657305.2017.1262475>
- Dahl, R. E., & Oglend, A. (2014). Fish price volatility. *Marine Resource Economics*, 29(4), 305–322. <https://doi.org/10.1086/678925>
- Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4), 1057–1072.
- DoF. (2018). Yearbook of fisheries statistics of Bangladesh 2017-18. Department of Fisheries, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.
- DoF. (2019). Yearbook of fisheries statistics of Bangladesh 2018-19. Department of Fisheries, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.
- Durbin, J., & Koopman, S. J. (2012). *Time Series Analysis by State Space Methods* (Second). Oxford University Press.
- Engle, R. F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of united kingdom inflation. *Econometrica*, 50(4), 987. <https://doi.org/10.2307/1912773>
- FAO. (2012). The state of world fisheries and aquaculture. *FAO*. <https://doi.org/10.1201/9780203869543-p6>
- FAO. (2020). The state of world fisheries and aquaculture 2020. *Sustainability in action*. Rome. <https://doi.org/10.4060/ca9229en>
- Gilbert, C. L., & Morgan, C. W. (2010). Food price volatility. *Philosophical Transactions of the*

- Royal Society B: Biological Sciences*, 365(1554), 3023–3034.
- Granger, C. W. J., & Newbold. (1974). Spurious nonlinear regressions in econometrics. *Journal of Econometrics*, 2, 111–120. <https://doi.org/10.1016/j.econlet.2004.10.016>
- Headey, D., & Fan, S. (2008). Anatomy of a crisis: the causes and consequences of surging food prices. *Agricultural Economics*, 39(1), 375–391.
- Hernandez, R., Belton, B., Reardon, T., Hu, C., Zhang, X., & Ahmed, A. (2018). The “quiet revolution” in the aquaculture value chain in Bangladesh. *Aquaculture*, 493(June 2017), 456–468. <https://doi.org/10.1016/j.aquaculture.2017.06.006>
- Hill, R. C., Griffiths, W. E., & Lim, G. C. (2011). *Principles of Econometrics* (Fourth).
- HLPE. (2014). Sustainable fisheries and aquaculture for food security and nutrition. *High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security*, June, 1–119. <http://www.fao.org/3/a-i3844e.pdf>
- Jacks, D. S., O’rourke, K. H., & Williamson, J. G. (2011). Commodity price volatility and world market integration since 1700. *Review of Economics and Statistics*, 93(3), 800–813. https://doi.org/10.1162/REST_a_00091
- Jalles, J. T. (2009). *Structural Time Series Models & the Kalman Filter: a Concise Review*. 1–30.
- Jarque, C. M., & Bera, A. K. (1987). A test for normality of observations and regression Residuals. *International Statistical Review / Revue Internationale de Statistique*, 55(2), 163. <https://doi.org/10.2307/1403192>
- Kat, H. M., & Heynen, R. C. (1994). Volatility prediction: a comparison of the stochastic volatility, GARCH (1,1) and Egarch (1,1) models. *Journal of Derivatives*, 2(2).
- Kwiatkowski, D., Phillips, P. C., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the althalternative of a unit root: how sure are we that economic time series have a unit root? *Journal of Econometrics*, 54(1–3), 159–178. [https://doi.org/10.1016/0304-4076\(92\)90104-Y](https://doi.org/10.1016/0304-4076(92)90104-Y)
- Lim, C. M., & Sek, S. K. (2013). Comparing the performances of GARCH-type models in capturing the stock market volatility in Malaysia. *Procedia Economics and Finance*, 5(13), 478–487. [https://doi.org/10.1016/s2212-5671\(13\)00056-7](https://doi.org/10.1016/s2212-5671(13)00056-7)
- Molnár, P. (2016). High-low range in GARCH models of stock return volatility. *Applied Economics*, 48(51), 4977–4991. <https://doi.org/10.1080/00036846.2016.1170929>
- Oglend, A., & Sikveland, M. (2008). The Behaviour of Salmon Price Volatility. *Marine Resource Economics*, 23(4), 507–526.
- Oglend, A., Asche, F., & Straume, H. (2021). Estimating Pricing Rigidities in Bilateral Transactions Markets. *American Journal of Agricultural Economics*, ajae.12230. <https://doi.org/10.1111/ajae.12230>
- Ott, H. (2013). Extent and possible causes of intrayear agricultural commodity price volatility.

- Agricultural Economics*, 45(2), 225–252.
- Rezitis, A. N., & Sassi, M. (2013). Commodity food prices : review and empirics. *Economics Research International*, 2013. <https://doi.org/http://dx.doi.org/10.1155/2013/694507>
- Sapkota, P., Dey, M. M., Alam, M. F., & Singh, K. (2015). Price transmission relationships along the seafood value chain in Bangladesh: aquaculture and capture fisheries. *Aquaculture Economics and Management*, 19(1), 82–103. <https://doi.org/10.1080/13657305.2015.994237>
- Schnepf, R. (2008). High agricultural commodity prices: what are the issues? *Nova Science Publisher, Hauppauge, NY, USA*.
- Toufique, K. A., Farook, S. N., & Belton, B. (2017). Managing fisheries for food security: implications from demand analysis. *Marine Resource Economics*, 33(1), 61–85. <https://doi.org/10.1086/694792>
- Trostle, R. (2008). Fluctuating food commodity prices. a complex issue with no easy answers. *Amberwaves*, 6(5), 10–17.
- Tveterås, S., Asche, F., Bellemare, M. F., Smith, M. D., Guttormsen, A. G., Lem, A., Lien, K., & Vannuccini, S. (2012). Fish is food - the FAO's fish price index. *PloS One*, 7(5).
- Wright, B. (2009). International grain reserves and other instruments to address volatility in grain markets. *Policy Research Working Paper 5028, The World Bank, Washington, DC, USA*.
- Wright, B. (2011). The economics of grain price volatility. *Applied Economic Perspectives and Policy*, 33(1), 32–58.