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ESTIMATION OF SUPPLY RESPONSE OF FISH IN BORNO STATE, NIGERIA

***[1]YaAshe M. Bulama, [2]Abba A. Makinta and [3]Usman A. Buba**
***Correspondence:** ymbulama@gmail.com

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Abstract
Fish is one of the richest animal proteins that is commonly consumed by both rich and people whose incomes are below the federal poverty threshold in Nigeria. The supply response of fish in Borno State, Nigeria was estimated. The study specifically analyzed the trend of quantity supplied of fish and estimated the responsiveness of fish supply to changes in price and non-price factors in Borno State. Time series data spanning January 2017 to December 2022 were obtained from the National Bureau of Statistics (NBS) and Food and Agriculture Organization Statistics (FAOSTAT). The data were subjected to a unit root test and analyzed using graphs and a vector error correction. The results indicated that there were fluctuations in the quantity of fish supplied overtime. The study also revealed the short and the long run relationships between the quantity of fish supplied and the prices of fish and its substitutes: dried tilapia, iced sardine, fresh tilapia, fresh African Arowana (Bargi), smoked catfish, fresh catfish, beef and chicken. Fish supply was revealed to be responsive to changes in price and non-price factors. It is recommended that fish farmers, processors, and marketers closely monitor changes in fish prices and substitute prices, and adjust their production and marketing strategies accordingly to, maximize their benefits and remain competitive in the market.

INTRODUCTION

Fish are among the most essential sources of food and income in the world. Production from global fisheries and aquaculture subsectors in 2016 reached an all-time high of 171 million metric tonnes, with a total value of $150 billion (Food and Agriculture Organization, 2018). This high level of production was driven by a combination of factors, including advances in fishing technology, increased investments in aquaculture, and growing demand for fish and fish products (Gephart *et al*., 2020; FAO, 2020). As a result, 88% of the fish produced is supplied across Africa, Asia, and the Pacific for direct human consumption (FAO, 2018). This high level of fish production and supply resulted in a high global average fish consumption of 20.3 kg/capita/year, which is 20% higher than the

[1,2,3]Department of Agricultural Economics, University of Maiduguri, Nigeria.

global average fish consumption in 2000 (FAO, 2018; World Health Organization, 2020). Furthermore, the growth in global fish production has also contributed to a 20% global increase in the income of many fish suppliers, particularly in developing countries where fishing and aquaculture are significant sources of income (World Bank, 2020; Ahmed *et al*., 2020).

Fish are a vital source of food and income globally, with Nigeria no exception. The country's fish production has been on the rise, reaching 1.3 million metric tons in 2022, valued at N320 billion (Odioko and Becer, 2022). This growth is attributed to increased aquaculture production, which accounted for 65% of the country's total fish production in 2022 (FAO, 2022). Nigeria's fish trade is also significant, with the country importing 1.5 million metric tonnes of fish in 2022, valued at N420 billion (Central Bank of Nigeria, 2022). Despite these gains, Nigeria still struggles to meet its domestic fish demand, leading to a significant reliance on imported fish.

The country's inability to meet its domestic fish demand is evident in the significant supply-demand gap. The total domestic fish production in Nigeria was estimated at 1.02 million metric tonnes in 2020 (National Bureau of Statistics, 2022). However, the country's total fish consumption requirement is estimated to be approximately 2.7 million metric tons (Oyetola *et al*., 2022). This indicates a supply-demand gap of approximately 1.7 million metric tonnes. This gap highlights the need for increased investment in Nigeria's fisheries sector, particularly in aquaculture, to reduce reliance on imports and meet the country's growing demand for fish.

In the quest to meet the domestic needs of fish consumers in Borno, fish farmers and sellers began to develop various means of storing the fish in order to preserve it for a longer period and moreover, to package it and get it across to other places where there is scarcity (Belton *et al.*, 2022). However, the raging Boko Haram insurgency in the northeast hit Baga, where the state's fish supply mostly comes from. It was reported that the insurgents occupied the supply area and halted the business, leaving the fishers and processors out of business, leading to shortages and price hikes (Bello *et al.*, 2017).

The government attempted to restore the fish supply in Borno by deploying more troops and constantly patrolling the affected zones until the supply became steady and normal again (Mordi 2022). Furthermore, the supply of fish in the study area continued to soar to the point of being in excess, which brought the fish prices low and led to less emphasis on aquacultural fish farming in the state as girls and many other hawkers fried, dried or smoked the excess fish and sold them along streets. This circumstance affected the price as well as supply of fish. Thus, supply became responsive to price changes, among other factors.

Supply response deals with how the quantity of any farm commodity offered for sale fluctuates in response to price changes. This factor is primarily concerned with the output response to a price adjustment, while holding other factors that affect the supply constant. It is common in theory and practice for such responses to be caused by one or more of the following factors. First, it depends on whether there was a price increase or decrease, second, by altering the scale or size of the farm, and third, technical advancement under production influences. Supply response, in this context, is the study of supply shifters (Obayelu and Ebute, 2016).

Despite its importance, empirical research on the supply response of fish in the region is lacking. Existing studies on fish production, marketing, and processing have not adequately addressed the supply dynamics of fish in Borno State, Nigeria. This study aims to fill this knowledge gap by estimating the supply response of fish in Borno State, Nigeria using the Vector Error Correction Model (VECM), which is a multivariate model. Specifically, this research seeks to quantify the short-term and long-term effects of price changes on fish supply, providing valuable insights for policymakers, fish farmers, and marketers. Thus, this study estimated the supply response of fish in Borno State, Nigeria by describing the trend of quantity of fish supplied in Borno from 2017 to 2022 and estimating the responsiveness of fish supply to changes in price and non-price factors in Borno from 2017 to 2022.

Hypothesis of the Study

The hypothesis is as follows:

i. There is no significant relationship between the supply response of fish and changes in fish price and non-price factors;

Theoretical Framework

Theory of Supply

The theory of supply is the basis of supply response analysis, which is widely used to analyze the supply response of farmers to changes in prices, weather, and other factors (Askari and Cummings, 1977). The theory of supply is a fundamental concept in economics that describes the relationship between the price of a good or service and the quantity supplied by producers (Gans *et al*., 2014). The law of supply states that, ceteris paribus, an increase in the price of a good or service leads to an increase in the quantity supplied (Lucas, 1967).

Assumptions of the Supply Theory

1. Perfect Competition: The theory of supply assumes perfect competition, where many firms produce homogeneous products, and no single firm has the power to influence the market price (Stiglitz, 1987).
2. Rational Behavior: This theory assumes that firms behave rationally, with the aim to maximizing profits (Kreps, 1990).
3. Constant Costs: This theory assumes that production costs remain constant, even as the quantity supplied changes (Varian, 2014).

Strengths of the Supply Theory

1. Predictive Power: The theory of supply has strong predictive power, allowing economists to forecast changes in quantity supplied in response to price changes (Gould and Ferguson, 1980).
2. Simplistic yet Effective: Supply theory is a simple yet effective framework for understanding firms' and markets' behaviors (Kreps, 1990).
3. Empirical Support: Numerous empirical studies have confirmed the validity of the supply theory (Askari and Cummings, 1977).

Weaknesses of the Supply Theory

1. Assumes Perfect Competition: The theory of supply assumes perfect competition, which is rarely observed in real-world markets (Stiglitz, 1987).
2. Ignores Externalities: The theory of supply ignores externalities, such as environmental or social costs, which can affect the quantity supplied (Pigou, 1920).
3. Oversimplifies Firm Behavior: The theory of supply oversimplifies firm behavior, assuming that firms only respond to price changes (Cyert and March, 1963).

METHODOLOGY

The Study Area

The area of study is Borno State, North-Eastern, Nigeria. The state lies between latitudes 10^{o}N and 13^{o}N and longitudes 11.40^{o}E and 14.40^{o}E (fig. 1). The state shares international borders with Cameroun to the East, Niger to the North, and the Republic of Chad to the North-East. The climatic conditions are harsh, with high temperatures fluctuating between 38^{0}C and 44°C and a mean rainfall of about 500 to 750mm per annum (Bulama *et al.*, 2019).

The major occupations in the state are farming, fishing and marketing dried tilapia, iced sardine, fresh tilapia, fresh African Arowana (*Bargi*), smoked and fresh catfish. The supply of fish in Borno State, Nigeria, is mainly from catch fisheries and aquaculture, but is often inadequate to meet demand, because most of the fish is taken to other parts of the country (Bukar *et al*., 2018). Sales are primarily through markets and roadside vendors.

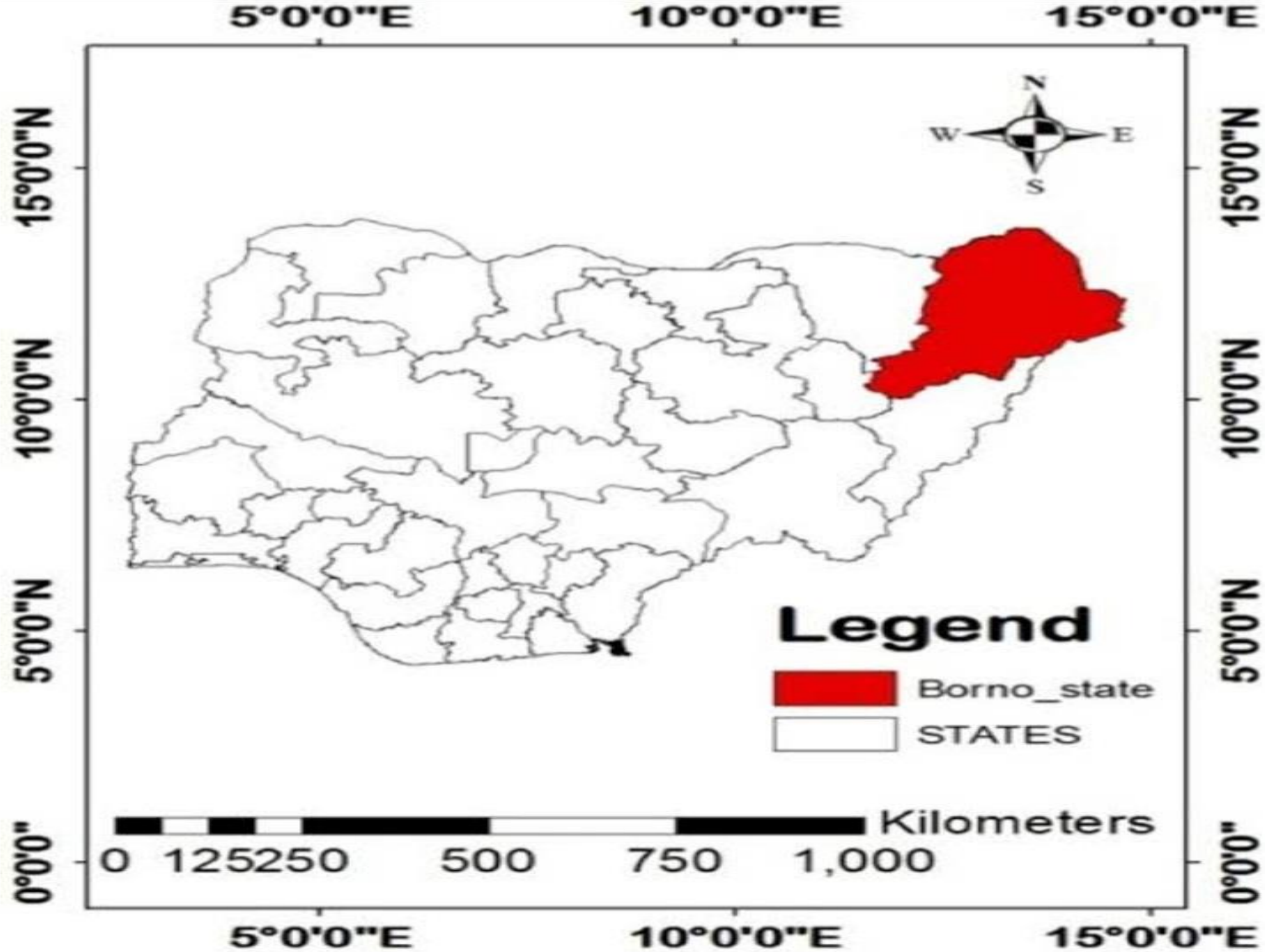

Figure 1: Map of Nigeria showing Borno State.

Source: Bukar *et al*., 2018.

This study estimated the supply response of fish in Borno State, Nigeria. It employed monthly time series data for 6 years spanning January 2017 to December 2022. The factors studied include, the quantity supplied of fish, prices of fish, and prices of substitutes such as beef and chicken.

The study employed time series data from secondary sources, including Food and Agriculture Organization Statistics (FAOSTAT) for the fish supply information, and the National Bureau of Statistics (NBS) for the fish price information.

. Monthly information on: quantity of fish supplied, prices of fishes such as: dried tilapia, iced sardine, fresh tilapia, price of fresh African Arowana (*Bargi)*, smoked catfish, and fresh catfish, and prices of substitutes such as, beef and chicken were used. Data pertaining to 72 months (6 years), spanning January 2017 to December 2022 were used for the study. They results were analyzed using STATA 14.2 and SPSS 20. Methods used included the unit root to test for stationarity using Augmented Dickey Fuller and the Vector Error Correction Model to address the supply response issue using E-Views 13.

Unit Root Test

Most economic time series trend overtime and must undergo appropriate transformation to achieve stationarity. The unit root test was performed to check the order of stationary of the data (in order to avoid spurious relationship). Non-stationary time series data tend to cause estimation, inference, and forecasting problems in empirical modeling. To free the data of these empirical problems, non-stationary data are transformed into stationary data through the unit root test. The objective is to convert an unpredictable process to one that has a mean return to a long-term average and a variance that does not depend on time. A variable considered stationary if it has a time-invariant mean and variance, and the covariance between the two periods does not depend on the length of the estimation period but on the lag between the periods. The most frequent used transformation process used in practice is integration or differencing (Rufino, 2011).

According to Bulama (2019), Rufino (2011), Acquah and Owusu (2012); Obayelu and Alimi (2013), if one identifies the series to be non-stationary, the first difference of the series is tested for Stationarity to determine the order of integration. A stationary series must be integrated of order zero or I (0) because it is not required to undergo differencing before attaining stationarity.

Most economic time series are I (1), that is, they generally become stationary only after taking their first difference. In general, if a non-stationary series must be differenced d times to make it stationary, it must be integrated of order d or I (d). The two well-known stationarity tests in the literature are the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979), and the Phillips-Perron (PP) test (Phillips and Perron, 1988).

For this study, the ADF (Augmented Dickey-Fuller) test was used due to its simplicity and ease of interpretation. The test was conducted on the level and first differences in the price series to obtain results at I(0) and I(1) orders, respectively. The following ADF regression equation was used to test for stationarity:

$$\Delta Y_{it} = \beta_1 + \beta_2 t + \delta Y_{it-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{it-1} + \varepsilon_t \text{ --- } 1$$

Where; β_1 is a constant, β_2 is the coefficient on a time trend;

δ is parameter that signifies the presence or absence of a unit root;

Y_{it} is a vector to be tested for co-integration, that is the price of cattle in the ith market;

t is the time or trend variable; i=1, 2, 3, …, n (ith market)

$$\Delta Y_t = Y_t - Y_{t-1}; \text{ --- } 2$$

Y_t is the price time series; Δ is the first difference operator;

Y_{t-1} is the lagged value of the price series; α_i is the coefficient of the lagged values of Y_{t-1}; and

ε_t is a pure white-noise error term; and m is the lag order.

The null hypothesis that $\boldsymbol{\delta}=0$ is tested against the alternative that $\boldsymbol{\delta}< 0$.

Vector Error Correction Model

The Vector Error Correction Model originated from The Error Correction Model, which was first suggested by Granger (1981), and later it was extended, used to develop estimation procedures, tests and empirical examples by Engle and Granger (1987). They theorized that the Error Correction Model is a dynamic time-series model, which has similarities to the partial adjustment model but is not the same. According to this model, there is some lag time for y_t to adjust to changes in x_t. So, y_t^*, a latent unobserved variable is introduced. The value that y_t would take if the economy were to have no frictions of any kind, that is, if all adjustments could occur instantaneously. The latent variable is assumed as a linear regression model depending on x_t and υ_t, the error process. It is considered to include a long-run relationship. The idea is that, if there is a change in x, y will change but, it will take some time to adjust, and eventually, it will change. Therefore, in the long term, there is a contemporaneous relationship between y_t^* and x_t. The particular adjustment process differs between the error correction model and partial adjustment. The model is expressed as follows:

$$y_t^* = \theta_t + \theta_2 x_t + \upsilon_t \text{ ……………………………………………………………………….} 3$$

$$y_t - y_{t-1} = \lambda\left(y_t^* - y_{t-1}\right) + \phi\left(x_t - x_{x-1}\right) \qquad \text{......4}$$

Substituting equation. 3 in 4, we have:

$$y_t = y_{t-1} + \lambda\left(\theta_1 + \theta_2 x_t + \upsilon_t - y_{t-1}\right) + \phi\left(x_t - x_{x-1}\right)$$

$$y_t = y_{t-1} + \lambda\theta_1 + \lambda\theta_2 x_t + \lambda\upsilon_t - \lambda y_{x-1} + \phi x_t - \phi x_{x-1}$$

$$= \lambda\theta_1 + \left(\lambda\theta_2 + \phi\right) x_t - \phi x_{x-1} + \left(1-\lambda\right) y_{t-1} + \lambda\upsilon_t \qquad \text{......5}$$

Where:

$\lambda\theta_1 = \beta_1$ = Constant term

$\lambda\theta_2 + \phi = \beta_2$ = short-run coefficient

$-\phi = \gamma$ = Coefficient of estimated lag for Xs

$\left(1-\lambda\right) = \rho$ = speed of adjustment

$\lambda\upsilon_t = \varepsilon_t$ = white noise error term

$$y_t = \beta_1 + \beta_2 x_t + \gamma x_{t-1} + \rho y_{t-1} + \varepsilon_t \qquad \text{......6}$$

Equation 6 is the error correction model which is an autoregressive distributed lag model of one lag on dependent and one lag on independent variable, (ADL (1, 1) Model) that can be estimated using OLS, which will give consistent estimates and is free from bias (Johansen, 1988).

The model in equation 5 did not tell us the dynamics of x_t and y_t but just a whole range of lags of y_t and x_t. So, there is no real economic concept, and secondly, y and x are non-stationary, it is a spurious regression model. To avoid spurious regression, the considered variables should be non-stationary in levels, but they must become stationary after first differencing, i.e., they should be I (1), Zero mean, constant variance, and without seasonal effects. The residuals of the estimated model should also be stationary. If the residuals are stationary, then the considered variables are co-integrated or have a long-run relationship or long-run equilibrium relationship between them. Two series are said to be co-integrated, if they are both integrated of the same order, if there is a linear combination of the two-time series (stationarity) and if the series are never drifting too far away from each other. So, to address the economic problems and spurious regression, we take the first difference and make our series stationary as shown below:

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 x_{t-1} + \rho y_{t-1} + \varepsilon_t \qquad \text{......} \qquad 7\, Y_t - Y_{t-1}$$

$$= \beta_0 + \beta_1 x_t + \beta_2 x_{t-1} - (1-\rho) y_{t-1} + \varepsilon_t$$

$$\Delta y_t = \beta_0 + \beta_1 x_t - \beta_1 x_{t-1} + \beta_1 x_{t-1} + \beta_2 x_{t-1} - (1-\rho) y_{t-1} + \varepsilon_t$$

$$\Delta y_t = \beta_0 + \beta_1 \Delta x_t - \lambda(y_{t-1} - \alpha - \beta x_{t-1}) + \varepsilon_t \qquad \text{......8}$$

Where:

$\lambda = 1-\rho$ = speed of adjustment

$\beta = \dfrac{\beta_1 + \beta 2}{1-\rho}$ = long-run coefficient

y_t = dependent variable

Δ = differencing operator

β_o = constant term of short-run

α = long-run constant term

β_1 = short-run coefficient

ε_t = white-noise error term

$\beta_1 + \beta_2 \Delta x_t$ = short-run dynamics

$y_{t-1} - \alpha - \beta x_{t-1}$ = long-run dynamics

The Vector Autoregressive Model (VAR) is often represented by Vector Error Correction Model (VECM) when long-run relationship exists. Vector auto-regression (VAR) was introduced by Sims (1980) as a technique that could be used by macroeconomists to characterize the joint dynamic behavior of a collection of variables without requiring strong restrictions of the kind needed to identify underlying structural parameters. It has become a popular time-series modeling method. The vector error correction mechanism (VECM) is used to account for the short-run dynamics between the explained and explanatory variables in a model. Even when a long-run relationship exists among variables, there may be short-term disequilibrium. Hence, the error correction equation is used to remove this divergence from long-run equilibrium. If a linear combination of the variables exists in a model, that is, stationary variables are be co-integrated. Given that the error correction representation is a function of the co-integrating relations, the co-integrating relations between the variables of the VECM model are first determined and then the VECM is estimated for possible short-run dynamics between the variables of the model. The following specified VECM models were used:

$$\Delta \ln q_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_1 ECT_{t-1} + \upsilon_{1t} \qquad 9$$

$$\Delta \ln bp_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_2 ECT_{t-1} + \upsilon_{1t} \qquad 10$$

$$\Delta \ln pdtl_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_3 ECT_{t-1} + \upsilon_{1t} \qquad 11$$

$$\Delta \ln pis_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_4 ECT_{t-1} + \upsilon_{1t} \qquad 12$$

$$\Delta \ln pftl_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_5 ECT_{t-1} + \upsilon_{1t} \qquad 13$$

$$\Delta \ln pft_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_6 ECT_{t-1} + \upsilon_{1t} \qquad 14$$

$$\Delta \ln psc_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_7 ECT_{t-1} + \upsilon_{1t} \qquad 15$$
$$\Delta \ln pfc_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_8 ECT_{t-1} + \upsilon_{1t} \qquad 16$$
$$\Delta \ln pch_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \ln q_{t-i} + \sum_{j=1}^{k-1} \beta_j \Delta \ln bp_{t-j} + \sum_{m=1}^{k-1} \beta_m \Delta \ln pdtl_{t-m} +$$
$$\sum_{n=1}^{k-1} \beta_n \Delta \ln pis_{t-n} + \sum_{n=1}^{k-1} \beta_o \Delta \ln pftl_{t-o} + \sum_{n=1}^{k-1} \beta_p \Delta \ln pft_{t-p} + \sum_{n=1}^{k-1} \beta_q \Delta \ln psc_{t-q} +$$
$$\sum_{n=1}^{k-1} \beta_r \Delta \ln pfc_{t-r} + \sum_{n=1}^{k-1} \beta_s \Delta \ln pch_{t-s} + \lambda_9 ECT_{t-1} + \upsilon_{1t} \qquad 17$$

Where:

$\ln q_t$ = log of quantity supplied of fish

$\ln bp$ = log of beef price

$\ln pdtl_t$ = log of the price of dried tilapia fish

$\ln pis_t$ = log of the price of iced sardine

$\ln pftl_t$ = log of price of fresh tilapia

$\ln pft_t$ = log of the price of fresh African Arowana (*Bargi*)

$\ln psc_t$ = log of the price of smoked catfish

$\ln pfc_t$ = log of the price of fresh catfish

$\ln pch_t$ = log of the price of chicken

α = intercept (constant term)

K-1 = the lag length that is reduced by 1

Δ = differencing operator

β_i, β_j, β_m, β_n, β_o, β_p, β_q, β_r, and β_s = short-run dynamics coefficients of the model' long-run equilibrium

λ_1 - λ_9 = speed of adjustment of the nine equations

i, j m, n, o, p, q, r, and s = lag order

ECT_{t-1} = the error correction term, which is the lagged value of the residuals obtained from the co-integration regression of the dependent variable on the regressors. The proposed model contains long-run information derived from the long-run co-integration relationship.

υ = residuals (stochastic error term often called impulses, or innovations or shocks)

***A priori* Expectation**

Variables	**Signs of Coefficients**
Price of Fresh Tilapia	Positive
Price of Fresh African Arowana	Positive
Price of Fresh caught Catfish	Positive
Price of Iced Sardine	Positive
Price of Smoked Catfish	Positive
Price of Dried Tilapia	Positive
Price of Beef	Negative
Price of Chicken	Negative

Coefficients of the Error Correction Term	Negative

RESULTS AND DISCUSSION

Trend in Fish Supply

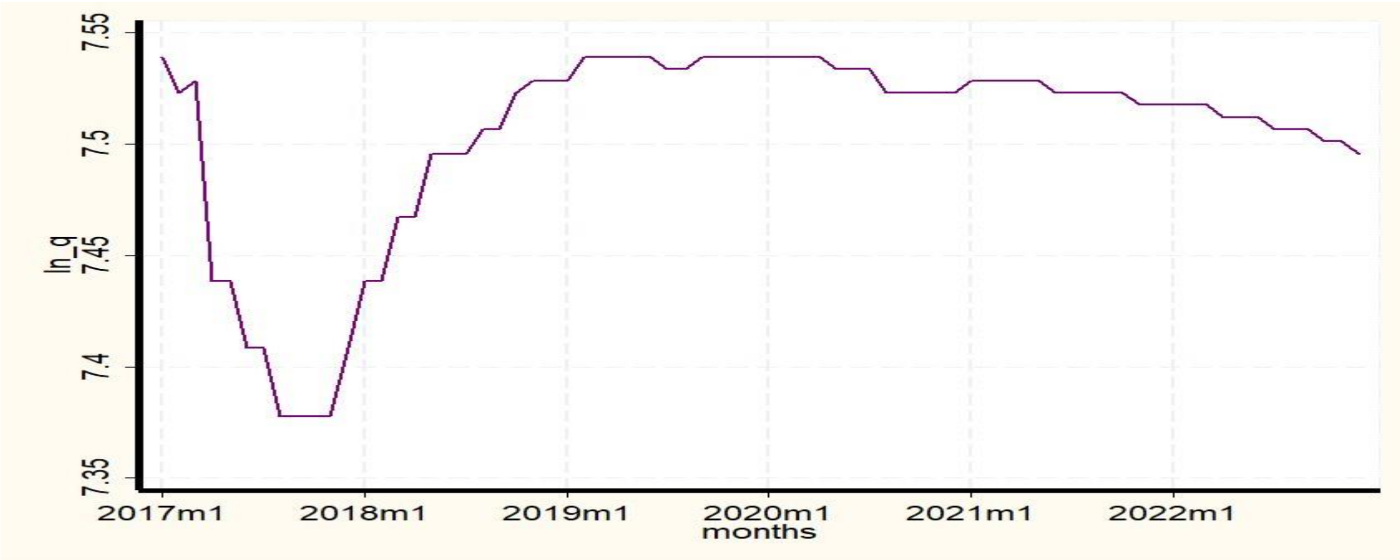

Figure 2: Trend in Fish Supply

Source: Computed from fish supply data, 2023

Supply of fish showed downward trend in 2017. This sudden downward trend in 2017 may be due to supply shocks experienced from the major fish supply in the Baga area, as reported by Bello *et al.*, (2017). It might also because of the high cost of fish feed, which made the suppliers use low quality feed that affected fish production and supply.

A steady increase was observed from 2018 to early 2019. This steady supply increase may be due to the restoration of the problem of insurgency from the major source of fish in the state.

Afterward, a continuous downward trend was observed from mid-2019 to 2022. The price might be related to government policy. This is in line with the findings of Muhammad *et al.* (2022) who reported that there was disruption in fish supply, which was exacerbated by the lockdown policy implemented by the government of Borno State in May 2020. This continuous downward trend, may also be due to the fall in prices of the major commonly consumed fish in the state as there was a continuous increase in production and supply from the state aquacultural sector to bridge the gap of shortage in the catch fisheries from the major source of fish supply, that is, Baga.

Unit Root Test

Table 1: Unit Root Result

Variable	level			1st Difference		
	ADF Test-Stat	1%C-value	Prob.	ADF Test-Stat	1%C-value	Prob.
LNQ	1.285831	-3.527045	0.631	-13.88122	-3.527045	0.0001
LNPDTL	2.079238	-3.525618	0.2536	-7.748185	-3.527045	0.0000
LNPIS	-0.167191	-3.528515	0.9369	-4.942553	-3.528515	0.0001
LNPFTL	-0.212814	-3.525618	0.9312	-5.969706	-3.527045	0.0000
LNPFT	-1.461581	-3.525618	0.5472	-6.785955	-3.527045	0.0000
LNPFC	-1.045660	-3.528515	0.7323	-9.381194	-3.528515	0.0000
LNPSC	-1.283825	-3.527045	0.6328	-11.46379	-3.527045	0.0001
LNPB	-0.786526	-3.525618	0.8166	-10.44802	-3.527045	0.0001

LNPCH	1.093204	-3.525618	0.9971	-7.935328	-3.527045	0.0000

Source: Computed from fish price data, 2023.

Table 1 presents the unit root test based on Augmented Dickey–Fuller (ADF) under the null hypothesis of the presence of a unit root (non-stationary) and the alternative hypothesis, which implied stationarity in the series. The Schwarz Information Criterion (SIC) provided the best fit for lag selection. It ensured that in the series, there were no serial correlation by providing guides on the number lags to be used. It was revealed that the series were non-stationary at level I(0) with ADF test statistics smaller than the 1% critical values (C-value). It became stationary after first differencing I(1) with ADF test statistics greater than the 1% critical value (C-value). The null hypothesis of non-stationarity was accepted at the level and rejected after taking the first difference of the series, and the alternative hypothesis of presence of stationarity was rejected in level form of the series and accepted after first differences of the series. Thus, the series was stationary after the first differencing and was further tested for supply responsiveness through the VECM.

Supply Response of Fish

The Vector Error Correction Model was used to estimate the long-run and short-run effects of changes in fish supply due to price changes of fish and its substitutes.

Table 2: The Long-run and Short-run Estimate of Supply Response of Fish in Borno

Variable	Coefficient	Std-error	t-value	P-value
Long-run Estimate				
LNQ	1.000000			
LNPFC(-1)	0.835575	(0.14545)	[5.74479]***	
LNPSC(-1)	0.643080	(0.27052)	[2.377191]**	
LNPB(-1)	-0.736812	(0.12205)	[-6.03718]***	
LNPCH(-1)	- 0.309388	(0.10481)	[-2.82195]**	
C	0.005503			
Short-run Estimate				
ECM	-0.606336	(0.17447)	[-3.47540]	0.0010**
D(LNQ(-1))	0.412168	(0.10895)	[3.78298]	0.0004**
D(LNPDTL(-1))	0.240052	(0.09658)	[2.48563]	0.0161**
D(LNPIS(-1))	0.309388	(0.10964)	[2.8221]	0.0243**
D(LNPFTL(-1))	0.368930	(0.13253)	[2.78369]	0.0074**
D(LNPFT(-1))	0.275633	(0.11479)	[2.40113]	0.0211**
D(LNPFC(-1))	0.410580	(0.11720)	[3.50332]	0.0023**
D(LNPSC(-1))	0.454367	(0.15813)	[2.87333]	0.0052**
D(LNPB(-1))	-0.416256	(0.08676)	[-4.79760]	0.0000***
D(LNPCH(-1))	-0.379953	(0.09132)	[-4.16087]	0.0001***
C	-8.79E-05	(0.00411)	[-0.02139]	0.9830
R-squared =	0.818746			
Adj. R-squared =	0.771754			
F-statistic =	17.42316			
Log likelihood =	1283.444			
Akaike information criterion	-31.98388			
Schwarz criterion	-26.15578			
Durbin-Watson	2.272213			
Prob(F-statistic)	0.000000			

*** = 1%, and ** = 5% significance level

Source: Computed from fish price and Supply data, 2023.

Table 2 presents both the long-run and short-run relationship of the quantity of fish supplied with the prices of fish and its substitutes. All variables except price of chicken were statistically significant at the 1% and 5% levels. The variables price of dried tilapia, price of iced sardine, price of fresh tilapia, and price of fresh African Arowana (*Bargi*) are co-integrated with the dependent variable, quantity of fish supplied. This implies that there exhibits linear relationship among the variables and therefore common long-run effects.

The long-run coefficients with respect to the price of fresh catfish and the price of smoked catfish are 0.835575 and 0.643080, respectively, with their associated t-statistic values of 5.74479 and 2.377191 being statistically significant at 1% and 5%, respectively. This shows that in the long term, the price of fresh catfish and the price of smoked catfish will increase significantly with an increase in the quantity supplied of fish. Thus, it implies that, eventually they have a positive and significant impact on the of fish quantity supplied. This may be because fresh fish and smoked fish have supply chain interdependence, and thus, they move along the same curve, if all things are equal. The coefficients of the price of beef is -0.736812, and that of the price of chicken is -0.309388, with their associated t-statistic values of -6.03718 and -2.82195 being statistically significant at 1% and 5%, respectively. This reveals that the prices of beef and chicken have negative and significant impacts on the quantity supplied of fish in Borno over the long term. This may be possible because beef and chicken are imperfect substitutes of fish, and they also move together.

Table 2 shows the coefficients of short-run dynamic variables; DLNQ (-1), DLNPDTL (-1), DLNPIS(-1), DLNPFTL(-1), DLNPFT(-1), DLNPFC(-1), DLNPSC(-1), DLNPB(-1), DLNPCH(-1) and the ECM coefficients. The coefficients of the lagged values of quantity supplied of fish, price of dried tilapia, price of iced sardine, price of fresh tilapia, price of African Arowana (*Bargi*), price of fresh catfish, and price of smoked catfish are all positive. This means that a previous increase in the quantities of these variables could increase the current quantity supplied in the short run. In the short run, a dynamic increase in the prices of beef and chicken could lead to a decrease in the quantity of fish supplied.

The results of the short-run analysis indicate positive and significant relationship between previous year's quantity supplied and current's year quantity supplied at the 5% level. This implies that in the short term, 0.412 increase in the previous quantity of fish supplied would lead an increase in the current quantity of fish supply by 1 unit. This is possible because the current quantity of fish supplied could be affected by its past price and past quantity supplied.

Coefficients of the lagged values of price of dried tilapia, price of iced sardine, price of fresh tilapia, price of fresh African Arowana (*Bargi*), price of fresh catfish, and price of smoked catfish showed a positive and significant relationship with quantity of fish supplied. This clearly indicates that lagged prices of these fish have positive short-run effects on the quantity of fish supplied to Borno, State, Nigeria. This implied that the quantity supplied of fish is responsive to previous increase in the prices of these fish in short-run. This agrees with the theory of supply, which states a positive relationship between prices of any commodity and quantity supplied (Mankiw, 2018). This clearly indicates that any increase in the prices of these fish will lead to an increase in the quantity of fish supplied. The positive signs of the coefficients also indicate that the short-term prices are adequate without causing oversupply that may result in a negative (inadequate) response to supply.

The coefficients of the price of beef and chicken were negative and significant at 1%, which is in line with the *a priori* expectation. The negative signs of the price of beef and chicken portray the negative effects of the price of beef and chicken on the quantity of fish supplied, even in the short-run. The possible reason could be that in the short-run, beef and chicken are substitutes for fish supplied in Borno State, Nigeria. Thus, the quantity of fish supplied is negatively responsive to change in the prices of beef and chicken in short-run.

As expected, the Coefficient of Error Correction Term in the short- run has a negative sign and statistically significant (-0.606336). This coefficient of ECM indicates that 61% of the disequilibrium between short and long-run impacts of the prices of fish and its substitutes on the quantity of fish supplied is corrected in each period compared with the previous or next period. This agrees with the findings of Ogunbadejo and Oladipo. (2016), which showed that 82% of all deviations of the fish variables in the short-run were corrected in long-run. The model's AIC value of -31.8 provided strong evidence for its validity. This negative AIC value indicates that the model's log-likelihood is larger than the penalty term for model complexity, which suggested best fit for the model. This was the case for Burnham and Anderson (2002); Konishi and Kitagawa, (2008). Their AIC value suggests that the model efficiently captures the underlying relationships between the variables.

Conclusion

It can be concluded that the quantity supplied of fish was not stable overtime, as there were upward and downward trends. The supply of fish is also responsive to the change in fish prices and non-price factors as most of the variables were statistically significant and positive.

It is recommended that the government implement price stabilization measures to reduce price fluctuations in fish prices, thereby minimizing market risks and protecting farmers' income. In addition, policymakers and stakeholders in the fish industry should consider the long-term relationships between fish prices and quantity supplied when making decisions, as changes in one variable can have lasting impacts on the others. Fish farmers, processors, and marketers closely monitor changes in fish prices and substitute prices, and adjust their production and marketing strategies accordingly, to maximize their benefits and remain competitive in the market.

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