Autoregressive Integration Moving Average (ARIMA) Model for Prices of Selected Grains in the South West Nigeria

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ABSTRACT
Background: Price serves as signals of relative scarcity as well as abundance of a given agricultural product. Prices of agricultural products vary from month to month and even from day to day and this constitutes a source of risk to farmers whose livelihood depends on good pricing of their products.

Method: This study was conducted to identify pattern of price dynamics and to develop model for price dynamics of beans, yellow maize and local rice using monthly price data of grains from the National Bureau of Statistics (2006-2015).

Result: The rk of the beans followed a regular decline ranging from 0.4035 to 1 while those (rk) of yellow maize and local rice follow non regular decline with the range 0.1448 – 1(yellow maize) and 0.2945 -1 (local rice) thus indicating that the data are non-stationary. The corrected Akaicke information criteria (AICC) and other information obtained for the ARIMA1,2,2 were higher than those of ARIMA2,2,2. The AICC obtained for the ARIMA1,2,2 are 958.422 (beans), 1178.169 (yellow Maize) and 12 11.778 (local rice). The ARIMA2,2,2 was thence favored above ARIMA1,2,2.

Key words: Correlogram, Droop, Heteroscedastic, Hop, Signal.

INTRODUCTION
Price according to business dictionary is a value that will purchase a finite quantity, weight or other measure of goods or a value that is put to a product or service. Price is a result of activities including calculations, research and understanding as well as risk taking ability (Economic Times, 2019). Prices of agricultural products vary from month to month and even from day to day and this constitutes a source of risk to farmers whose livelihood depends on good pricing of their products. Prices also differ between various grades of products and also differ between alternative markets and it (price) serves as signal of the relative scarcity as well as abundance of a given agricultural product (Akintunde et al., 2012). Beans, maize and rice are among the staple grains that are highly valued in Nigeria (Akpan et al., 2014). The prices of these grains are also said to be highly heteroscedastic seasonally and market-wise (Gieri et al., 2015). Beans and these other grains are sensitive to weather condition variability and this thus makes their cultivation very difficult (Akintunde, 2012). This (sensitivity to weather condition) coupled with unfavorable price fluctuation of the commodities can frustrate farmers’ efforts and thus constitute a risk to farmers.

Previous study on time series analysis (Abu et al., 2015) has examined acreage response of soybean to price in Nigeria. Also, monthly price analysis of cowpea (Beans) and Maize in Akwa Ibom State, Nigeria (Akpan et al., 2014). Forecasting of meteorological drought using ARIMA model (Karthika et al., 2017) and Hectrage Response of some selected cereal crops to price and non- price factors in Nigeria (Tahir, 2014) have been conducted. These works nevertheless, there exist little or no known work on the price dynamics of the selected grains in the Southwest, Nigeria and for the period under study. The goal of time series analysis has been identification of systematic pattern and random noise as well as trend analysis (Montgomery, 1990). These two goals are important to strategic planning of food supply for ensuring food security of a nation. The practical application of the present study is therefore in the forecasting and modeling of prices of these grains for profit maximization and risk management by farmers as well as for strategic grain reserves planning. The objective of this study was therefore to identify pattern of price dynamics and to develop model for future price dynamics of beans, yellow maize and local rice.

MATERIALS AND METHODS
Data for this study were obtained from the National Bureau of Statistics (NBS) formerly, Federal office of Statistics, Oyo State, Ibadan. The study area was the urban market of the South West Nigeria (Oyo, Ondo, Ogun, Osun, Lagos and Ekiti States) between the year 2006 and 2015. The South West Nigeria is one of the six geographical regions of the...
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country and it falls between longitude 2°31' and 6°00' East and Latitude 6°21' and 8°37'N and cover a land area of 77,818 km². The region is having boundary with Edo and Delta States in the East and in the North by Kwara and Kogi States while in the West it is bounded by the Republic of Benin and in the South by the Gulf of Guinea. The States were predominantly Yoruba States with other tribes found in large chunks and are largely agrarian in nature. The region has a tropical climate and bless with 2 usually distinct (wet and dry) seasons. The wet seasons last from April to October while the dry season last from November to March. Mean annual rainfall of the region falls between 1,000 to 3,000mm and mean temperature ranges from 21°C to 31°C.

The data obtained were subjected to descriptive statistics (mean, variance and standard error) and autocorrelation. Let \( X_t \) be a discrete time series or a process then the autocorrelation or lagged correlation is defined as the correlation of the process against a time shifted version of itself (Box and Jenikins, 1976). It is given as;

\[
\rho_k = \frac{\sum_{t=1}^{N-1} (X_t - \overline{X})(X_{t-k} - \overline{X})}{\left( \sum_{t=1}^{N-1} (X_t - \overline{X})^2 \right)^{1/2} \left( \sum_{t=1}^{N-1} (X_{t-k} - \overline{X})^2 \right)^{1/2}}
\]

Where \( \overline{X} \) is the mean of the first N-1 observation and \( \overline{X} \) is the mean of the last n-1 observation. \( X_t \) is the first N-1 which is \( X_{N-1}, t=1,2,3,4,... N-1 \) and \( X_{t-k} \) is the last N-1 which \( X_{N-k}, t, 2,3,4,... N-1 \)

The ARIMA model otherwise depicted as ARIMA (p, d, q) is of general form;

\[
X_t = a_1 X_{t-1} + a_2 X_{t-2} + ... + a_p X_{t-p} + b_1 t_{t-1} + b_2 t_{t-2} + ... b_q t_{t-q} + \epsilon_t
\]

Where \( a_1, a_2, ..., a_p \) are the response variable at lag time \( t-1, t-2, ..., t-q \); \( b_1, b_2, ..., b_q \) are coefficient of past errors at the lag time; \( \epsilon_t \) is the first \( N-1 \) which is \( 1,2,3,4,...N-1 \)

The ARIMA model is in line with general ARIMA model proposed by Box and Jenkins (1970).

Two (2) ARIMA models, ARIMA(1,2,2) and ARIMA(2,2,2) were investigated and their model statistics including the adjusted coefficient of determination which indicates the proportion of the variance in the dependent variable (Y) that is predicted or explained by the ARIMA model. Four processes are involved in the use of ARIMA model for time series data and include identification (of data trends), estimation (of the model coefficient), model checking for efficiency and forecasting (Assis et al., 2010). These 4 processes were employed in the current study.

### RESULTS AND DISCUSSION

**Descriptive statistics of the price of the grains**

The annual average price of the beans increases but not steadily over the years and ranged between ₦60,960 for 2007 and ₦251,110 for 2013. The variance ranged between 34,697 for 2010 and 689,687 for 2012 (Table 1). The average prices of yellow maize are non-regular and ranged from ₦40,399 (for 2008) to ₦135,768 for 2013. The variance however has a very wide range of 12,081 (for 2016) and 6948.16 for 2007. Mean price of the local rice was found to fall between ₦53,129 for 2006 and ₦207,384 for 2013 while the variances were from 1.077 for 2006 and 8527.77 for 2013 (Table 1). The implications of these results are:

1. The variability of the prices have high/wide margin with the rice having the highest of the margin.
2. Average annual prices of the beans were the highest while the average annual price of yellow maize were the least.

The average monthly prices of the beans returned an increasing trend for the first 9 months (January – September) of the year. It ranged between ₦138,094 and ₦158,329 for September (Table 2). The average monthly price of the beans for the remaining months dropped to ₦149,143 for December. The variance is generally very high and ranged between 6106.80 for May and 8745.75 for September. The average monthly price of yellow maize was generally low and ranged between ₦34.697 for February and ₦96.413 for November (Table 2). The variance is also generally high but lesser than that of beans and it ranged between 674.564 for October and 4968.15 for May. The average monthly price of rice ranged between ₦104,785 for January and ₦131,547 for June while the variance fell between 1793.39 for November and 11688.95 for May. The implications of the results are:

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**Table 1: Summary of Annual Price of the Grains.**

| Variables | Beans | Maize | Rice |
|-----------|-------|-------|------|
|           | Mean ± SE | Variance | Mean ± SE | Variance | Mean ± SE | Variance |
| 2006      | 67.407 ± 1.859 | 41.484 | 41.621 ± 1.003 | 6948.16 | 12.081 | 53.129 ± 0.300 | 1.077 |
| 2007      | 60.960 ± 3.764 | 169.997 | 72.175 ± 24.063 | 6948.16 | 78.653 ± 12.376 | 1837.84 |
| 2008      | 77.312 ± 2.521 | 76.246 | 40.399 ± 1.149 | 15.831 | 75.488 ± 2.628 | 82.873 |
| 2009      | 102.383 ± 3.077 | 113.601 | 55.232 ± 2.107 | 53.25 | 69.048 ± 7.896 | 748.166 |
| 2010      | 87.908 ± 1.700 | 34.697 | - | - | 91.534 ± 2.499 | 74.942 |
| 2011      | - | - | 74.641 ± 2.495 | 74.682 | 118.674 ± 4.46 | 239.751 |
| 2012      | 224.088 ± 7.581 | 689.687 | 95.520 ± 0.902 | 9.756 | 144.274 ± 0.687 | 5.664 |
| 2013      | 251.110 ± 4.453 | 237.964 | 135.768 ± 17.848 | 3822.69 | 207.384 ± 26.658 | 8527.77 |
| 2014      | 234.944 ± 2.269 | 61.779 | 107.293 ± 4.845 | 281.671 | 176.387 ± 9.856 | 1165.68 |
| 2015      | 228.788 ± 4.138 | 205.440 | 94.623 ± 3.069 | 113.007 | 165.036 ± 2.895 | 100.553 |

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Table 2: Summary of Monthly Price of the Grains.

| Variables | Beans       | Maize       | Rice        |
|-----------|-------------|-------------|-------------|
|           | Mean ± SE   | Variance    | Mean ± SE   | Variance    | Mean ± SE   | Variance    |
| January   | 138.094±26.164 | 6161.03    | 71.313 ±10.981 | 1085.34    | 104.785±14.596 | 2130.69    |
| February  | 140.077± 26.390 | 6268.01    | 68.672 ±10.653 | 1021.44    | 104.806±14.932 | 2229.76    |
| March     | 147.84 ± 28.703 | 7414.73    | 73.182 ± 10.458 | 984.296    | 113.164 ± 15.351 | 2356.49    |
| April     | 144.384 ± 27.975 | 7043.40    | 73.597 ± 10.621 | 929.141    | 108.194±17.938 | 3217.85    |
| May       | 144.739 ± 26.049 | 6106.80    | 88.864±23.495  | 4968.15    | 128.29 ± 34.189 | 11688.95   |
| June      | 147.918± 26.256 | 6204.33    | 88.721 ± 23.438 | 4944.06    | 131.547 ± 33.740 | 11383.76   |
| July      | 154.553 ± 28.045 | 7078.60    | 77.310 ± 12.905 | 1498.80    | 112.175 ± 13.961 | 1949.08    |
| August    | 155.567 ± 28.001 | 7056.67    | 82.892±12.243  | 1348.96    | 125.037 ± 18.310 | 3352.72    |
| September | 158.329 ± 31.173 | 8745.75    | 73.042 ± 9.813  | 866.611    | 118.076 ± 14.353 | 2060.17    |
| October   | 153.890 ± 28.334 | 7225.28    | 69.831 ± 8.657  | 674.564    | 121.623 ± 18.967 | 3597.40    |
| November  | 145.324±28.452  | 7285.74    | 96.413±20.739   | 3870.80    | 124.341±13.392  | 1793.39    |
| December  | 149.143 ± 29.933 | 8063.97    | 92.523±18.588   | 4300.06    | 123.489±14.562  | 2120.55    |

1. Bean had the highest average monthly price while yellow maize had the least average monthly price.
2. The monthly price (N) of the rice returned the highest variability.

The trend of the series plot established in the present work conflict with the time series plot of rice production in the entire Nigeria (Aina et al., 2015) which can be described a random series. This dissimilarity might have been caused by the difference in the study areas (South west and Nigeria) and parameters (price and production) of the two studies.

The results of the visual analysis in the present study clearly depict non stationary of the price data and it is in line with Dickey and Pantula (2002). Also, the non-stationary nature of the price of the grains in the present study is similar to Abu et al (2015) for soybean acreage response to price fluctuation. It was maintained that if a series does not seem to have a constant mean and the plot of the estimated autocorrelations dies down very slowly with increasing j, then the series is non-stationary. Similarly, the hops of the time series might have been caused by naturally occurring...
phenomena like the Boko haram saga and other security challenge in the Country. Two phenomena have been identified for sudden hop in series plot and are naturally occurring phenomena and quasi-experiment (Chatfield, 2003). Similarly, price instability was established by the area of acreage allocation for soybean cultivation (Abu et al., 2015), political instability, oil price fluctuation, population growth and climate change (Mustapha and Culas, 2019). Nature of product, fluctuation of currency exchange rate and poor infrastructure were identified as causes of price fluctuation in Kilimanjaro, Tanzania (Huka et al., 2014). There existed an indication of food crisis in the series plots obtained and it is in conformity with Iokekwu (2019) who maintained that Africa Countries are facing a worsening food crisis unseen in the last 30 years. In addition, the high/wide variability margin for the commodities’ price with the rice having the highest of the margin can be hinged on persistency of the price instability factors established by early authors. Also, Kassim (2012) established that consumer price instability can be linked with persistent factors such as season, input price changes, production and marketing technologies and consumer taste.

Visual analysis of price dynamics and correlelogram of the selected grains

Generally, the visual analysis of the series indicated that beans returned higher prices over the period while the yellow maize was the least (Fig 1). The visual analysis of the time plots of the grains (bean, yellow maize and local rice) returned an increasing cyclical trend for the period. It was however noticed that the series showed low trends for the first half of the period and later hop for the latter part of the period (Fig 1). The implication of the results is that the prices of the commodities rose up tangentially after some period of the study. The results of the visual analysis of the price index of the beans indicated that beans’ price index was regular while those of yellow maize and local rice were random (Fig 2). The implication of the result is that price dynamics for both yellow maize and local rice are almost the same and thus followed a regular random pattern. The implication of this result is that the rate of change of the three commodities (beans, yellow maize and local rice).

The visual analysis of the correlogram for all the grains (Fig 3) showed that the autocorrelation, \( r_k \), die down as the lag increases. It was also obtained that the \( r_k \) for both local rice and yellow maize followed the same pattern while the \( r_k \) for beans followed different pattern and was the highest at any of the lag. The \( r_k \) of the beans followed a regular decline ranging from 0.4035 to 1 while those \( r_k \) of yellow maize and local rice follow non regular decline with the range 0.1448 – 1(yellow maize) and 0.2945 -1 (local rice). This
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indicates that as the period of the study increases, the relationships between the price of any of the commodities and the previous price decreases. Also, from the visual analysis, it is glaring that the data are non-stationary and thus would require differentiation for further analysis.

From the visual analysis, series plots obtained in the present study can be partitioned into two distinct parts, early and reduced price of the commodities and latter and increased commodities price period. The hop nature of the prices of the commodity in the latter period under study is not in conformity with the steady rise in the price of both commodities in the Northern Nigeria (Akanni, 2014). The hop of this time series data is however similar to average crop prices and percentage change in Africa obtained from FAOSTAT by Mustapha and Culas (2019). The ARIMA model components (particularly the intercept) revealed that the non-stationary nature of the initial data have been removed after the first differentiation based on the negative intercept obtained for all the models.

The ARIMA model components and statistics

The analysis of the autoregressive moving average model of the beans returned the model components that are not significantly different from zero except the first moving average (MA1 – Table 3). The $t_{112, 0.05} = 4.6$ obtained for the MA1 is significant ($P < 0.05$) while that of other model components (0.29 = AR1; -1.06 = AR2; -1.28 = MA2 and -0.2 = intercept) were not significant. The standard errors of the estimates were generally low (less than unity) and ranged between 0.06 for the intercept and 0.295 for the AR1). For the yellow maize, the ARMA model components were all significant except the intercept. The $t_{112, 0.05} = 6.23$, -3.7, 19.9 and 9.46 obtained respectively for AR1, AR2, MA1 and MA2 were significant ($P < 0.05$ – Table 3). The standard error of the ARMA model estimates fall between 0.016 for the intercept and 0.106 for AR1.

The model statistics for the ARIMA model indicated that high standard error ranging from 20998.333 (beans) to 138609.41 (local rice) and high variance (959.471 – 1959.471).
The parsimony of the ARIMA\(_{(1,2,2)}\) model in the forecasting of weekly price of Green beans, 1178.169 (yellow maize) and 1211.778 (local rice) were obtained. The adjusted \(R^2\) of the model are 0.967, 0.46 and 0.660 for beans, yellow maize and local rice. Also, the corrected Akaie information criteria (AICC) obtained were 959.471, 1156.716 and 1187.905 for bean, yellow maize and local rice. The model prediction for the beans followed a similar trend (of increasing cyclical but non regular trend) with the original prices (Fig 4). This indicated a parsimonious prediction and it is in line with the adjusted coefficient of determination \((R^2 = 0.967)\) obtained for the model. The ARMA\(_{(2,2,2)}\) model prediction for yellow maize also has similar random but increasing trend with the original price data (Fig 5). The adjusted coefficient of determination \((R^2 = 0.469)\) obtained for the model is also an indication of good prediction though lesser than that of the model for the beans. The visual analysis of the model prediction for the local rice returned a similar cyclical but non regular trend for the price of rice (Fig 6). The model statistics for the ARMA\(_{(1,2,2)}\) model on the other hand gave a higher variance of the estimates including 185.764, 1179.751 and 1568.693 for bean prices, yellow maize prices and local rice prices respectively. Similarly, the corrected Akaie information criteria (AICC) and other information obtained for the ARIMA\(_{(1,2,2)}\) were higher than those of ARIMA\(_{(2,2,2)}\). The AICC obtained for the ARIMA\(_{(1,2,2)}\) are 958.422 (beans), 1178.169 (yellow Maize) and 1211.778 (local rice – Table 5).

The implication of these results is that each of the ARIMA\(_{2,2,2}\) model can sufficiently predict the price of the commodities at any period of time than the ARMA\(_{1,2,2}\) model and that this prediction are done at different level of reliability. The parsimony of the ARIMA\(_{2,2,2}\) model arrived at in this study is similar to Assis et al., (2010) which established that Mixed ARIMA model outperformed other investigated models for cocoa bean price forecasting. It was also found suitable for forecasting food grains production in Bangladesh (Lasker et al., 2013). ARIMA\(_{2,2,2}\) was found to outperformed ARIMA\(_{1,2,2}\) or of any other order though with the AICC far more than those of Kirimi (2016). This may be hinged on the nature of the data in both studies (Present study and Kirimi, 2016). GARCH model was however preferred to ARIMA model in the forecasting of weekly price of Green gram (Pani et al., 2019). This difference might have been due to the fact that pricing in each study case might be affected by disparate factors.

**CONCLUSION**

The grain deficit of the nation (Nigeria) in conclusion has been established using behavioural model in previous study (Akanni, 2014). Efficient utilization of the instrument of the time series analysis results in the current study and similar studies can be an asset in optimum grain production for self-sufficiency in food production especially in this era of rice importation ban. It is therefore recommended that farmers should be guided based on the grain price dynamics on grain production for profit maximization and the grain reserve body should utilize the price regime dynamics for adequate grain reserve activities.

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