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Time Series Analysis on Paddy Rice Production in Ghana

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Abstract:
The study assessed time series analysis on paddy rice production in Ghana. The research attempted to investigate the trend nature of rice paddy production in Ghana with historic data from 1961 to 2015 and hence model for future statistics using the Box-Jenkins methodology of time series analysis. In the descriptive statistics it was revealed that the skewness and kurtosis is positive indicating that most of the values are concentrated on the left of the mean and peaked. Also the data can be best described to follow an exponential growth trend however not stationary and had to be differenced. The ARIMA (0, 1, 2) model estimated was found accurate and hence forecast made for 2016-2020.The result obtained from this research should serve as a guide to investigate the trend of production. It is further recommended for the model to be reviewed over time and re-estimated when necessary.

Keywords: *Time series analysis, linear trend model, quadratic trend model, autocorrelation function, partial autocorrelation function, stationarity, parameter estimation, parsimonious model and differencing*

1. Introduction

Rice is considered to be the second most important grain food staple in Ghana, next to maize(MOFA, 2009). According to Provash & Imon(2008) rice is the most important food in the world since more than half of the world's population depends on rice for food calories and protein, especially in developing countries. It is an important commodity accounting for about 15% of Ghana's Gross Domestic Product (GDP). About 45% of the total area planted in the country to cereals is mainly rice (Kranjac-Berisavljevic, 2000).

The year 2004 was declared International Year of Rice by the United Nations with the theme 'Rice is life', the first time an international year has been focused on one crop. According to the Assembly, by so doing they affirm the need to heighten awareness of the role of rice in alleviating poverty and malnutrition. The Assembly also emphasized the need to turn world attention on the role rice as a staple crop can play in attaining internationally agreed development goals (United Nation Information Service, 2004).

Rice production takes place in all the ten regions of Ghana; which also cover all the major ecological-climatic areas including the interior savannah area, the high rain forest zone, the semi-deciduous rain forest area and the coastal savannah area with peak production occurring in the Northern, Upper East, Western, BrongAhafo and Volta Regions (ODI, 2003). Since 1978, the bulk of the country's rice produce comes from the Northern Regions, with the traditional mode of cultivation being lowland rain-fed rice culture (Ibrahim, 1981). The main rice types produced in Ghana are *Oryza Sativa* and Oryza Glaberima (Angelucci F. et al, 2013) Some of the varieties of rice produced in Ghana include Mandi, GR 18 (Afife), and Farro 15 which are exotic breeds and indigenous breeds such as Kpukpula and Anyofula.

Domestic production of rice in Ghana has been less than consumption needs for a long period of time. Imports of rice have been increasing steadily since 1980s, and are contributing more than 50% of all rice consumed in the country. Demand for rice began to overwhelm supply due to population increase and improved standard of living. Unreliable production and marketing arrangements have also contributed to this situation, consequently, the huge government imports in order to compensate for the short fall in supply (Dogbe, 1996). The increase in demand can be attributed in a large part to rapid urbanization and ease of cooking and storage. Imported rice is also perceived to be of better quality than local rice and thereby reported to command higher prices (Bimpong, 1998).

Rice is by every account an important crop in the Ghanaian diet and its availability throughout the year is very important, it will however be very difficult for the country in present circumstances to achieve self-sufficiency in rice production. This could be achieved through area expansion or increased output per unit area. However, production constraints such as land tenure problems, removal of subsidy on inputs, absence of water control systems lead to high-risk and non-intensive cropping practices. Other problems include low yields and low profitability, reduction of soil productive capacity, coupled with over liberalization of rice trade in Ghana, locally cultivated rice is often unattractive to prospective buyers or consumers, and sometimes not available to them at all (Seidu, 2008).

1.1. Problem Statement

In 2014, rice consumption in Ghana experienced a tremendous growth up to 748,000 Metric Tonnes. Out of this, over 55% (414,000MT) was imported costing Ghana over 290 million US dollars of its scarce foreign currency (USDA, 2015). This is at a time where the country hits its maximum total area cultivated of about 221,000 hectares giving a paddy produce of 602,499MT and 417,000MT of milled rice.

There are several past and current projects conducted in the country with the aim of improving rice production in the West African region. An example is Quality Rice Development Project implemented by Savanna Agricultural Research Institute (SARI) and the Fievie Rice Project all with the objective of increasing productivity of rice in the three regions of the north and the Volta Region respectively.

To be able to meet the ever-increasing demand of rice in the market, it is necessary to undertake an objective study on recorded figures on rice production, analyse them and make predictions to inform and prepare authorities for the future. In light of this, it is necessary to use time series techniques which can better describe and model rice production in Ghana.

1.2. General Objective

The main objective is to develop an appropriate time series model of predicting annual rice paddy produced in Ghana.

1.3. Specific Objectives

- To determine the trend/pattern of rice production in Ghana.
- To determine an accurate model that best describes data on paddy rice production.
- To make a 5 year forecast of rice production beyond the period under study.

1.4. Justification

Agriculture is often described as the backbone of Ghana's economy; hence, the need for a solution to bridge the gap between consumption and production cannot be over emphasized. With rice being the second most important grain in the country, and several failed attempts being made by government and other agencies to improve quality and quantity of rice produced to meet set targets. It has become necessary to examine the trend in production and make forecast of future productions, assessing our ability to meet future targets hence this study.

1.5. Limitationof Study

The study was limited to the following:

- Time constraint since the study was carried concurrently with academic work and work since the study leave secured was partially granted.
- Accessing data as data has become a very difficult thing to access in Ghana these days.

2. Literature Review

Rice, Oryza *Sativa* or OryzaGlaberrima, is a cereal food plant of the grass family Gramineae (commonly known as Poaceae). It is extensively cultivated in warm climates, especially in East Asia producing seeds that are cooked and used as food. Rice has fed more people over a longer period of time than any other crop. As far back as 2500 B.C. rice has been documented in the history books as a source of food and for tradition as well (Khan, Afroz, & Mohiuddin, 2013).

The origins of rice scanty however begun in China and its surrounding areas. Its cultivation spread throughout Sri Lanka and India. It was then passed onto Greece and the Mediterranean areas and then Southern Europe and North Africa (Rost, 1997). From Africa it travelled to America through the 'Colombian Exchange' of natural resources-rice being a gift from the old world to the new world. From then on rice is being cultivated in the United States for the past 300 years (AIREA, 2012). Generally there are two rice species, Oryza*Sativa* known as Asian rice and OryzaGlaberrimaknown as African rice. *Oryza*Glaberrima is grown in West Africa due to its tolerance to severe climatic conditions, infertile soil, and iron toxicity amongst others. It is believed to have been domesticated over 2000 years ago around the Upper Niger River (Jones, Dingkuhu, Aluko, & Semon, 1997). Due to disadvantage of lower yields than the Asian rice species scientists managed to cross breed the two species to produce New Rice for Africa (NERICA). Rice was already one of the major commercial food crops in Ghana the 17th and 18th centuries. However it was not until 1960, that rice became an important crop in Ghana (Bozza, 1994). Before the 1920s, most of the rice in Ghana was grown in the Volta and Western Regions, with cultivation carried out mostly by females, while males focused on cash crops such as cocoa, rubber and coffee. Since the 1960s, the bulk of Ghana's rice has come from the Northern Sector of the country. From 1978-1980, the Northern Region produced 170,000 metric tons of paddy rice. This formed 61% of the total rice production in Ghana during the period (Akanko, Bimpong, Affram, & Achaab, 2000). It is therefore possible to conclude that promoting rice yield of rice in Northern Ghana could help the country achieve its food policy objective of attaining self-sufficiency in rice production.

According to Wikipedia (2016), worldwide there are about 40,000 varieties of rice. Grouped into four major categories of common characteristics:

- Glutinous rice: (also called sticky rice, sweet rice or waxy rice) is a type of rice grown mainly in Southeast and East Asia, which has opaque grains, very low amylose content, and is especially sticky when cooked. It is called glutinous in the sense of being glue-like or sticky.
- Aromatic rice: is one of the major types of rice. It is medium to long-grained rice. It is known for its nut-like aroma and taste, which is caused by the chemical compound 2-acetyl-1-pyrroline.
- Indica rice: grains are long to short, slender, somewhat flat, and the spikelets are awnless. Indica grains shatter more easily and have 23-31% amylose content. It is the major type of rice grown in the tropics and subtropics. It has broad to narrow, light green leaves and tall to intermediate plant stature (except for the semi-dwarf).
- Japonica rice: is a group of rice varieties from northern and eastern China grown extensively in some areas of the world. It is found in the cooler zones of the subtropics and in the temperate zones. It has narrow, dark green leaves, medium-height tillers and short to intermediate plant stature. Japonica grains are short, roundish, spikelets are awnless to long-awned, and grains do not shatter easily and have 0-20% amylose content.

In the Ghana, both local and exotic breeds are grown mostly with the aim of improving yield and their pest/disease resistance ability. Some varieties grown are GR 18, GR 19, Anyofula, Tox, Wita, etc.

According to Nutsugah et al. (2003), diseases, non-parasitic weeds, bird damage and insect pests cause substantial losses annually to the rice crop in Northern Ghana to be specific and the country as a whole. However many rice diseases and insect pests occur sporadically and can result in total crop loss. Common rice diseases that arise from natural infection in the fields are often foliar mostly causes by nutritional imbalance. Common rice foliar diseases that affect crops in the country are; Brown spot, Leaf blast, Narrow brown leaf spot, and Leaf scald. Pest such as Suckling bugs, Grasshoppers, Termites, Birds, and Caterpillars flub produce before harvest.

Rice is described as a main source of 35-60% dietary calories consumed by more than 3 billion people and probably the most versatile crop by Fageria et al. (2003). Rice is the foremost food of the developing world (Singh, 1985). It provides about 4/5 of the calories of the more than two billion people of Asia and one-third the calorie intake of the nearly one billion people of Africa and Latin America. It is further noted that food self-sufficiency and food security in majority of the Asian countries largely depends on rice self-sufficiency and rice security. Vaughan et al. (2003) considered rice crop as a major source of nutrition for about two-third of mankind. This involuntarily provides an avenue for an increased production in order to keep pace with the growing population in spite of its productivity seriously being affected negatively by biotic and abiotic factors (Zafar, Aziz, & Masood, 2004).

Many countries including Bangladesh, Thailand, Pakistan and Vietnam have their economies sustained largely through rice production. Such countries earn foreign exchange from the export of rice. The boosting of the rice industry in Malaysia has been an important source of foreign exchange savings as well as a means of channeling wealth to a poor sector of society and amongst all providing against a rice shortage in the event of regional or national political crisis (Brown, 1973).

In Africa, Jones et al., (1998) considered rice crop as the main staple food in at least 8 of the 17 countries of West Africa and rapidly gaining popularity as a major food among other crops. However, self-sufficiency in West African rice production is declining because demand is increasing at a rate of 5.9% annual growth since 1970, faster than its production of 4% annual growth over the same period. Despite the unavailability of exact statistics, it is estimated that over 80% of the under-resourced rice farmers in West Africa grow rice as a subsistence crop.

Ghana's inability to produce rice to self-sufficiency levels is indicative of the presence of major constraints in the rice industry requiring urgent attention. It is necessary to stem the trend of over-reliance on imports to meet the increasing demand for rice. Local potential resources for production should be exploited with sustainable strategies at all levels of the rice industry. This creates an urgent need to increase and improve the production of rice in Africa, particularly Ghana in order to meet the high demand (Ogunbayo, Ojo, Guei, & Oyelakin, 2005).

In Ghana rice production has been recognized as an important factor in the development of the agricultural sector for the improvement of the overall national economy since the nation attained independence in 1957. Various governments have supported rice production by adopting various measures with incentives for increasing food production for the achievement of food security objectives. In Ghana rice is produced in four main ecological areas, rain fed upland and lowland both in Northern Ghana, Inland swamp-inland valley of central Ghana and irrigated – Northern and Southern Ghana. The major challenge faced by local farmers is the high cost of production since most of the agricultural inputs are imported (Khor, 2006). Other constraints limiting production include lack of access to credit, shortage of water, pests, diseases, unavailability of suitable varieties, low quality of locally processed rice and inefficient markets for inputs and produce (Furuya & Sakurai, 2003).

Just like most African countries, Ghana is not self-sufficient in rice production and therefore relies heavily on imported rice to make up for the gap in domestic demand, despite the recorded increases in production (EAAE, 2007). Apparently, countries in the West African sub-region are in similar position and depend on imports to fill the gap between domestic demand for rice and production. By early to mid-1970s, Ghana was self-sufficient in rice production and even had some for export. However, currently commercial rice imports account for over 60%, food aid about 2%, and domestic production about 37% of total rice consumption (Asuming-Brempong & Osei-Asare, 2007).

In the last couple of decades domestic rice production in Ghana has been overwhelmed by domestic demand. In addition, domestic rice varieties cultivated have lagged behind changing consumer preferences toward aromatic and long-grain white rice. As a result, rice imports from Asia and America have grown considerably to fill the ever increasing demand gap for quality rice (MiDA, 2009).

In a bid to save foreign currency and ensure food security it has been the government's primary concern to increased production of domestic rice with higher competitiveness against imported rice (JICA, 2007).

The development of the entire Ghanaian economy is strongly linked to agriculture, since the agricultural sector constitutes about 40% of GDP. Agriculture is still mostly in the hands of small-scale farmers, including those cultivating rice.

Vision 2020 is the document outlining the Ghanaian policy for the development of the overall economy, including the agricultural sector. The Strategic Policy Framework outlines the methods that the Government of Ghana intends to use in order to reduce poverty and to stimulate the growth of the country's economy at a projected rate above 4% (Kranjac-Berisavljevic, 2000). The policies and programmes for the agricultural sector are formulated within AAGD Strategy (Accelerated Agricultural Growth and Development), based on elements such as the promotion of selected products, development and improved access to technology, access to financial services, improved rural infrastructure and enhanced rural infrastructure and institutional capacity.

The Agricultural Services Sector Investment Programme (AgSSIP) was another Government of Ghana instrument intended to assist the implementation of the government's agricultural strategies by various means, ultimately aimed at the reduction of rural poverty in the country through strengthening and empowering grassroots organisations, improvement of economic infrastructure, and improved access to inputs (Ofori, 2000).

Rice is still recognised as one of the vital crops for the country. Since January 2001, plans have been underway for rice imports into the country to be cut by 30% in an effort towards orienting the market to use locally produced grain. The Ghana Irrigation Development Authority is leading efforts to market local rice from irrigation projects under brand names such as 'Pride', 'Yenmo' and 'Rice Master', while trying to study the American methods for rice production and marketing and improve the processing quality.

Worldwide, several literatures have treated issues concerning growth trends in agricultural production. It is the view of Provash & Imon(2008) that a study of the trend of the production of rice is hugely important in thickly populated countries like Bangladesh, where rice is the main food and where and the entire economy hugely depends on the production of rice. For a country like Ghana where local production is not able to even out local consumption, the need for trend analysis in rice production cannot be overestimated.

A variety of trend models have been used in several works for analysing the production of major crops in other countries (Gupta et al. (1999), Sahu(2003)). Among them the linear trend model, the quadratic trend model and the compound trend model are very commonly used. Some efforts have been made to analyse trends of production of rice over the years using these models. But we observe that results obtained from most of the studies are not much supported from diagnostic viewpoint.

It is now evident that any statistical analysis that lacks diagnostics checking could produce much worse result than one can anticipate. All of the commonly used trend models largely depend on two basic assumptions: the normality of errors of the model and the non-existence of unusual observations (mainly outliers) in the data. In this study, we introduce diagnostic methods that are essential for examining the validity of assumptions the trend models require. We also investigate the forecast models from diagnostic viewpoint ensuring that we come out with the best possible model for rice production in Ghana.

2.1. Data and Source

The data for the study was mainly secondary historical annual data of paddy rice production obtained from the Statistics Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (MOFA), the data spans from 1961 to 2015.

2.2. Statistical Technique

Time series is an ordered sequence of values of a variable at equally spaced time interval. It can also be described as a collection of observation made sequentially in time, a set of observations (Y_t) each one being recorded at a specific time (t). Time series occur in a variety of field ranging agriculture to engineering. Many sets of data appear as time series, examples include; hourly observations made on the yield of chemical processes, a monthly sequence of goods sold in a supermarket and so on. Due to the frequent encounter of data of this form methods of analysing time series constitute a great importance in the area of statistics.

2.2.1. Objectives of Time Series Analysis

The main objectives of time series analysis are:

2.2.1.1. Description of Data

When presented with a time series data, the first step in the analysis is usually to plot the data and obtain simple descriptive measures of the main properties of the series such as seasonal effect, trend etc. The description of the data is usually done using summary statistics and or graphical methods like a time plot of the data.

2.2.1.2. Interpretation of Data

When observations are taken on two or more variables, it may be possible to use the variation in one time series to explain the variation in another series. This may lead to a deeper understanding of the mechanism which generated a given time series. For example, sales are affected by price and economic conditions.

2.2.1.3. Forecasting of Data

Given an observed time series, one may want to predict the future values of the time series. This is an important task in sales forecasting and in the analysis of economic and industrial time series. Prediction is closely related to control problems in many situations, for examples if we can predict that manufacturing process is going to move off target, the appropriate corrective action can be taken.

2.2.1.4. Control

A good forecast enables the analyst to take action so as to control a given process, whether it is an industrial process, or an economy or whatever. When a time series is generated which measures the quality of a manufacturing process, the aim of the analysis may be to control the process. In statistical quality control, the observations are plotted on control charts and the controller takes action as a result of studying the charts.

2.2.2. Components of a Time Series

Characteristic movement of time series may be classified into four main types often called components of time series. These four different components are trend, seasonal, cyclical and irregular or random variations.

- Trend (T_t) - The Trend of a time series also known as a secular trend is a relatively smooth pattern, regular and long term movement exhibiting the tendency of growth or decline over a period of time. The trend is that part which the series would have exhibited, has there been no other factors affecting the values.
- Seasonal effects (I_t) - Seasonal variation represents a type of periodic movement where the period is no longer than one year. The factors which cause this type of variation are the climatic changes of the different seasons, such as changes in rainfall, temperature, humidity, etc. and the customs and habits which people follow at different parts of the year. For short, a seasonal component is a pattern that is repeated throughout a time series and has a recurrence period of at most one year.
- Cycles (C_t) - Cyclical fluctuation is another type of periodic movement where the period is more than a year. Such movements are fairly regular and oscillatory in nature. One complex period is called a cycle.
- Residuals (E_t) – Irregular or Random variation movements are such variations which are caused by factors of an erratic nature. These are completely unpredictable or caused by such unforeseen events as flood, earthquake, strike, lockout, etc. It may sometimes be the result of many small forces, each of which has a negligible effect, but their combination effect is not negligible.

The idea is to create separate models for these four elements and then combine them. Generally, time series models are either additive in the form

$$Y_t = Tt + It + Ct + Et \qquad (3.1)$$

Or multiplicative

$$Y_t = Tt * It * Ct * Et \qquad (3.2)$$

2.3. Normality Test

The normality test is to investigate the extent to which the data collected approximate a normal distribution. The extent of normality of the data will be determined using skewness and kurtosis.

- Skewness; is the degree to which a data set is not symmetrical. Skewness can be evaluated via the skewness statistic. As data becomes more symmetrical, its skewness value approaches zero. Positive skewed or right skewed data has a value greater than 0 and the tail of such distribution points to the right. The reverse case applies for negatively skewed data.
- Kurtosis; is the degree to which a data set is peaked. Normally distributed data establishes the baseline for kurtosis not too flat or sharply peaked with a statistic of 0. A distribution with a sharper than normal peak will have a positive kurtosis value and is termed leptokurtic distribution, whereas, a platykurtic distribution has a flatter than normal peak and a negative kurtosis value.

2.4. Trend Analysis

Trend analysis fits a general trend model, thus, the linear, quadratic or exponential growth models to the time series data. This procedure is often used to fit trend when there is no seasonal component to the series. The trend most accurate to describe the series will be determined using the measures of accuracy, MAPE, MAD and MSD. The model with the minimum measure of accuracy is what best describes the series.

2.4.1. Trend Models

- Linear Trend Model; is estimated using the Ordinary Least Square estimation with a general model of
  $y_t = \beta_0 + \beta_1 t + e_t$ (3.3)
  Where y_t is the projected value of the y variable for a selected value of t, β_0 is the constant intercept; β_1 represents the average change from one period to the next.

- Quadratic Trend Model; which accounts for a simple curve is of the form
  $y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + e_t$ (3.4)
- Exponential Growth Trend Model; accounts for exponential growth or decay. Mathematically,
  $y_t = \beta_0 * \beta_1^t * e_t$ (3.5)

2.4.2. Measures of Accuracy

Three measures of accuracy of the fitted model are computed, MAPE, MAD, and MSD for each of the simple forecasting and smoothing methods. For all three measures, the smaller the value, the better the fit of the model. We use these statistics to compare the fits of the different methods.

- Mean Absolute Percentage Error (MAPE); measures the accuracy of fitted time series values, specifically in trend estimation. It usually expresses accuracy as a percentage and is defined by,
  $$MAPE = \frac{100\%}{n}\sum_{t=1}^{n}\left|\frac{At - Ft}{At}\right| \quad (3.6)$$
  Where A_t is the actual value, F_t equals the fitted value, and n equals the number of observations.
- Mean Absolute Deviation (MAD); expresses accuracy in the same units as the data, which helps conceptualize the amount of error. The mean deviation is a measure of how much the fitted value of the data is likely to differ from the actual value. The absolute value is used to avoid deviation with opposite sides cancelling each other out. Its mathematical form is,
  $MAD = \frac{1}{n}\sum_{t=1}^{n}|A_t - F_t|$ (3.7).
- Mean Squared Deviation (MSD); measures the square forecast error, error variance and also recognize that longest errors are disproportionately more expensive than small errors. It is expressed mathematically as,
  $MSD = \frac{1}{n}\sum_{t=1}^{n}|A_t - F_t|^2$ (3.8).

2.5. Autocorrelation Function

Autocorrelation is the correlation (statistical relation) between observations of a time series separated by k time units such that systematic changes in the value of one variable are accompanied by systematic changes in the other. The plot of autocorrelations is called the autocorrelation function or correlogram. The ACF is extremely useful in helping to obtain a partial description of the process for developing a forecasting model. ACF is mathematically the proportion of the auto covariance of y_t and y_{t-k} to the variance of a dependant variable y_t.

$$ACF(k) = \frac{cov(y_t, y_{t-k})}{var(y_t)} \quad (3.9)$$

2.6. Partial Autocorrelation Function

Partial autocorrelation function measures the degree of association between Y_t and Y_{t+k} when the effect of other time lags on Y are held constant. In other words, PACF is the simple correlation betweeny$_t$ and y_{t-k} minus the part explained by the intervening lags.

$$PACF = corr(y_t, y_{t-k}|y_{t-1}, y_{t-2}, \dots, y_{t-k+1}) \quad (3.10)$$

2.7. Stationarity

A stationary process has a mean and variance that do not change over time and the process does not have trends. To proceed with the estimation of an ARIMA model, the series is required to be stationary and to test for stationarity under this study we consider the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test.

2.7.1. Augmented Dickey-Fuller Test

For the ADF test, we test the hypothesis that;

- H_0: the series is not stationary.
- H_1: the series is stationary.

At 95% significance level, a p-value less than 0.05 means we reject H_0 meaning the series is stationary, else it is not stationary

2.7.2. Kwiatkowski, Phillips, Schmidt and Shin Test

The KPSS test has a reverse hypothesis to the ADF test hence;

- H_0: the series is stationary.
- H_1: the series is not stationary.

This means that at 95% significance level, a p-value less than 0.05 means we reject H_0 and say the series is not stationary, otherwise it is stationary.

2.7.3. Achieving Stationarity

To achieve stationarity, the series has to be differenced till it is stationary. However when the variability of the data increases over time, and has an exponential growth trend, the series can be log transformed before differencing to stabilise the variance. After each differencing, the tests for stationarity (ADF and KPSS tests) have to be performed again to ensure that the series is stationary.

2.8. Model Identification

After the series has been made stationary, the next step is to identify which model best describes the series. At this stage we decide how many autoregressive (p) and moving average (q) parameters are necessary to yield an effective but still parsimonious model of the process (parsimonious means that it has the fewest parameters and greatest number of degrees of freedom among all models that fit the data). In practice, the numbers of the p or q parameters very rarely need to be greater than 2 and the primary tools for doing this are the ACF and the PACF. The sample autocorrelation plot and the sample partial autocorrelation plot are compared to the theoretical behaviour of these plots shown below.

Process	ACF	PACF
AR(p)	Tails off	Cut off after the order p of the process
MA(q)	Cut off after the order q of the process	Tails off
ARMA(p, q)	Tails off	Tails off

Table 1: Theoretical Behaviour of the ACF and PACF for Model Identification

2.8.1. Autoregressive Process (Ar)

In statistics, an autoregressive (AR) model is a type of random process which is often used to model and predict various types of natural and social phenomena. Autoregressive models are based on the idea that the current value of the series, y_t, can be explained as a function of p past values, y_{t-1}, and $y_{t-2} \ldots y_{t-p}$, where p determines the number of steps into the past needed to forecast the current value. Mathematically, a time series autoregressive model is given by:

$$Yt = \phi 1\, yt-1 + \phi 2\, yt-2 + \ldots + \phi p\, yt-p + et \quad (3.11)$$

Where e_t is assumed to be a white noise process, ϕ_1, ϕ_2, ..., ϕ_p are the autoregressive model parameters and $1<\phi<1$ for all p. Each observation is made up of a random error component (e_t) and a linear combination of prior observations.

2.8.2.Moving Average Models (MA)

The moving average process expresses the current value of the observation in terms of the past shocks or residuals. This means that condition on the past values of the residuals, the future values of the series can be predicted. The notation MA (q) refers to the moving average model of order q. *A* moving average model of order q, abbreviated MA (q), is defined mathematically as:

$$Y_t = \mu + e_t - \theta_1 e_{t-1} - \cdots - \theta_q e_{t-q} \quad (3.12)$$

Where μ is the mean of the seriese_t, e_{t-1}... are white noise error terms and $\theta_1 \ldots \theta_q$ are the parameters of the model.

That is, a moving average model is conceptually a linear regression of the current value of the series against previous (unobserved) white noise error terms or random shocks. The random shocks at each point are assumed to come from the same distribution.

2.8.3 Autoregressive Moving Average Model (ARMA**)**

Autoregressive Moving Average (ARMA) models are typically applied to auto correlated time series data. Given a time series of data Y_t, the ARMA model is a tool for understanding and, perhaps, predicting future values in this series. The model consists of two parts, an autoregressive (AR) part and a moving average (MA) part. The model is usually then referred to as the ARMA (p, q) model where p is the order of the autoregressive part and q is the order of the moving average part. The notation ARMA (p, q) refers to the model with p autoregressive terms and q moving average terms. This model contains the AR (p) and MA (q) models.

An Auto-Regressive Moving Average model of order (p, q) abbreviated as ARMA (p, q), is defined mathematically as

$$Y_t = \mu + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + e_t - \theta_1 e_{t-1} - \cdots - \theta_q \theta_{t-q} \quad (3.13)$$

Where Y_t is a mixed autoregressive moving average process of orders p and q abbreviated ARMA (p, q).

2.8.4. Autoregressive Integrated Moving Average Models (ARIMA)

If a non-stationary time series which has variation in the mean is differenced to remove the variation the resulting time series is known as integrated time series. It is called integrated because the stationary model which is fitted to the differenced data as to be summed or integrated to provide a model for the non-stationary data. All AR (p) models can be represented as ARIMA (p, 0, 0) that is no differencing and no MA (q) part, also MA (q) models can be represented as ARIMA (0, 0, q) meaning no differencing and no AR (p) component.

The general model is ARIMA (p, d, q) where p is the order of the AR part, d is the degree of differencing and q is the order of the MA part. The general ARIMA (p, d, q) model can be expressed in terms of the backward shift operator as

$$(1-Ø_1B-Ø_2B^2-\ldots-Ø_PB^P)(1-B)^dY_t=(1+\theta_1B+\theta_2B^2+\ldots+\theta_qB^p)e_t \quad (3.14)$$

Where $(1-B)^d$ is the non-seasonal differencing filter.

2.8.5. Information Criteria

The following tools (criteria) are used in the selection of best fit model out of suggested models. The model with the minimum of these statistics is selected as the best fit.

- Akaike's Information Criteria (AIC); uses the maximum likelihood method. In the implementation of the approach, a range of potential ARMA models is estimated by maximum likelihood methods, and for each, the AIC is calculated, given by:

  $$AIC(p,q) = ln(\sigma_e^2) + r\frac{2}{n} + constant \qquad (3.15)$$

  Where, n is the number of observations in the historical time series data, σ_e^2 is the maximum likelihood estimate of σ_e^2, and $r = p + q + 1$ denotes the number of parameters estimated in the model. Given two or more competing models the one with the smaller AIC value will be selected.
- Schwarz's Bayesian Criterion (BIC); like AIC uses the maximum likelihood method. The BIC imposes a greater penalty for the number of estimated model parameters than does the AIC. The use of minimum BIC for model selection results in a chosen model whose number of parameters is less than that chosen under AIC. It is given by,

  $$BIC(p,q) = \ln(\sigma_e^2) + r\frac{\ln(n)}{n} \qquad (3.16)$$

- Corrected Akaike's Information Criteria (AIC_C); the AIC is biased estimator and the bias can be appreciable for large parameter per data ratios. Hurvich and Tsai (1989) showed that the bias can be approximately eliminated by adding another non – static penalty term to the AIC, resulting in the corrected AIC, denoted by AIC_C and defined by the formula:

$$AIC_C = AIC + \frac{2(r+1)(r+2)}{n-r-2} \qquad (3.17)$$

2.9. Parameter Estimation

Once a model is identified the next stage of the ARIMA model building process is to estimate the parameters. Estimating the parameters for the ARIMA (Box- Jenkins) models is a quite complicated non-linear estimation problem. For this reason, the parameter estimation was done using a statistical package called gretl.

2.10.Model Diagnosis

To ensure that the selected model is the best model that suits the data the following diagnostics are performed.

- Time Plot of the Residuals; is a plot of the standardized residuals against time. For a fit model, it should not show any fixed pattern, trend in the residuals, no outliers and in general case no changing variance across time.
- Plot of Residual ACF; allows one to examine the goodness of fit by means of plotting the ACF of residuals of the fitted model. If most of the sample autocorrelation coefficients of the residuals are within the 5% significance limits in a random pattern, then the model is a good fit.
- The Normal Q-Q Plot; is another diagnostic check on the residuals to determine whether it follows the normal distribution. This is done by using the normal probability plot Q–Q plot. It is a plot of the quantiles of two distributions against each other, or a plot based on estimates of the quantiles. The normal Q-Q plots is used to compare the distribution of a sample to a theoretical distribution. If most of the points are in line and closer to the normal line, then the model is a good fit.
- Ljung-Box Q Statistics; is a check of the overall model adequacy. The error terms are examined and for the model to be adequate the errors should be random. If the error terms are statistically different from zero, the model is not adequate. The test statistic used is the Ljung-Box statistic, a function of the accumulated sample autocorrelations, r_j, up to any specified time lag *m*. As a function of m, it is determined as:

  $$Q(m) = n(n+2)\sum_{j=1}^{m}\frac{r_j^2}{n-j} \qquad (3.18)$$

  Which is approximately chi-square distributed with n-p-q degree of freedom. Here p and q are orders of AR and MA respectively and n is the number of usable data points after any differencing operations. This statistic can be used to examine residuals from a time series model in order to see if all underlying population autocorrelations for the errors may be 0 (up to a specified point). If the corresponding p-value is greater than 0.05, then the model is considered adequate.

2.11. Forecasting

Once an appropriate time-series model is selected and established fit, we can now forecast future values of the series. Once a forecast is made for y_{T+1} it is added to the series and used to forecast for y_{T+2}. The process continues into the desired future for which a forecast is desired which for this study is the next five years.

2.11.1. The Box-Jenkins Method of Modelling Time Series

The Box-Jenkins methodology (Box & Jenkins, 1976) is a step-wise statistical method used in analysing and building forecasting models which best represents a time series. This method of forecasting implements knowledge of autocorrelation analysis based on autoregressive integrated moving average models.
The methodology has the following advantages;

- It is logically and statistically accurate
- It makes great use of historical time series data
- Forecasting accuracy is increase

The procedure is of four distinct stages namely; Identification, Estimation, Diagnostic checking, Forecasting.

- Identification: Identification methods are procedures applied to a set of data to indicate the kind of representational model that will be further investigated. The aim here is to obtain some idea of the values *p, d* and *q* needed in the general linear ARIMA model and to obtain initial estimates for the parameters. The task here is to identify an appropriate subclass of models from the general ARIMA family which may be used to represent a given time series. This requires examining the autocorrelation and partial autocorrelation coefficients calculated for the data.
- Estimation: Once the preliminary model is chosen, the estimation stage begins. The purpose of the estimation is to find the parameter estimates that minimize the mean square error. An iterative non-linear least squares procedure is applied to the parameter estimates of an ARMA (p, q) model. The method minimizes the sum of squares of error given to form the model and data. The estimates usually converge on an optimal value for the parameters with a small number of iterations.
- Diagnosis Checking: Residuals from the fitted model are examined to ensure that the model is adequate (random). Autocorrelation of the error term are estimated and plotted to determine whether they are statistically zero. Thus the observed value is test as a result of sampling error. This is the first test for adequacy. The second test for adequacy is the Q-test as discussed earlier. Under circumstances of unsatisfying results, other ARMA model may be tried until a satisfactory model is obtained.
- Forecasting: When a model is identified and validated, forecast for one period can be made and there on several periods. As the forecast period becomes further ahead, the chance of forecast error becomes larger. As new observations for a time series are obtained, the model should be re-examined and checked for adequacy. If the time series seem to be changing over time, the parameters of the model should be recalculated or a new model may have to be developed. When small differences in forecast error are observed, only a recalculation of the model parameters is required. However, if larger differences are observed in the size of the forecast error, then a new model is required, thus, returning to the first step of the Box-Jenkins process.

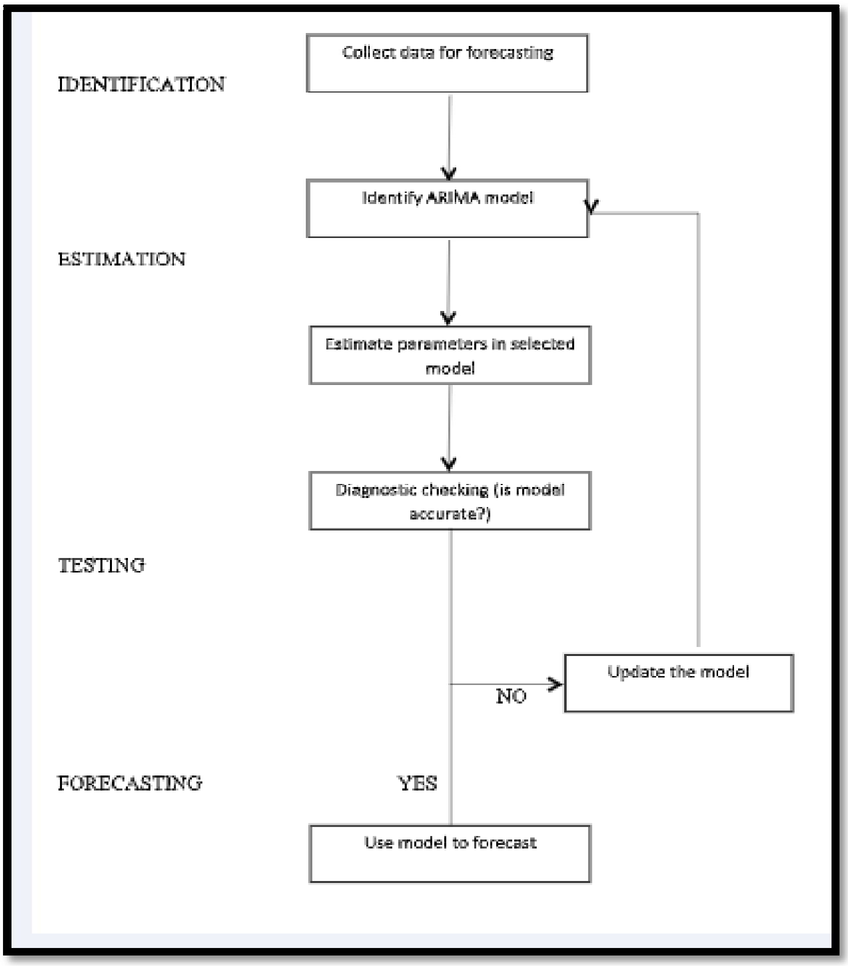

Figure 1: The Box-Jenkins Process

3. Results and Discussion

This chapter entails an analysis of the data on annual paddy rice production in Ghana with historic data from the year 1961-2015. The statistical computing tool employed for this work is mainly Minitab software and Gretl software, and the Box-Jenkins methodology of time series analysis is also used.

3.1. Preliminary Analysis

This preliminary analysis consists of the computation of the descriptive statistics in relation to the data, time series plots and a trend analysis.

3.1.1. Descriptive Statistics

Table 2below displays a table of the summary statistics of rice production in Ghana.

The minimum value in the data set is detected to be 30400MT and maximum 602499MT. An arithmetic mean of 170359MT was calculated with a standard deviation of 150534.19 indicating the data is scattered across the mean. The coefficient of variation 88.36 shows that the data has a very high variance. It also exhibits positive skewness of 1.39 indicating that most of the values are concentrated on the left of the mean and has a positive kurtosis of 1.16 which indicates that the data is leptokurtic, thus, a sharper than normal peak.

Description	Statistic
Mean	170359
Std. Deviation	150534.19
Coefficient of variation	88.36
Skewness	1.39
Kurtosis	1.16
Minimum	30400
Maximum	602499

Table 2: Descriptive Statistics of Rice Production

3.1.2. Time Series Plot

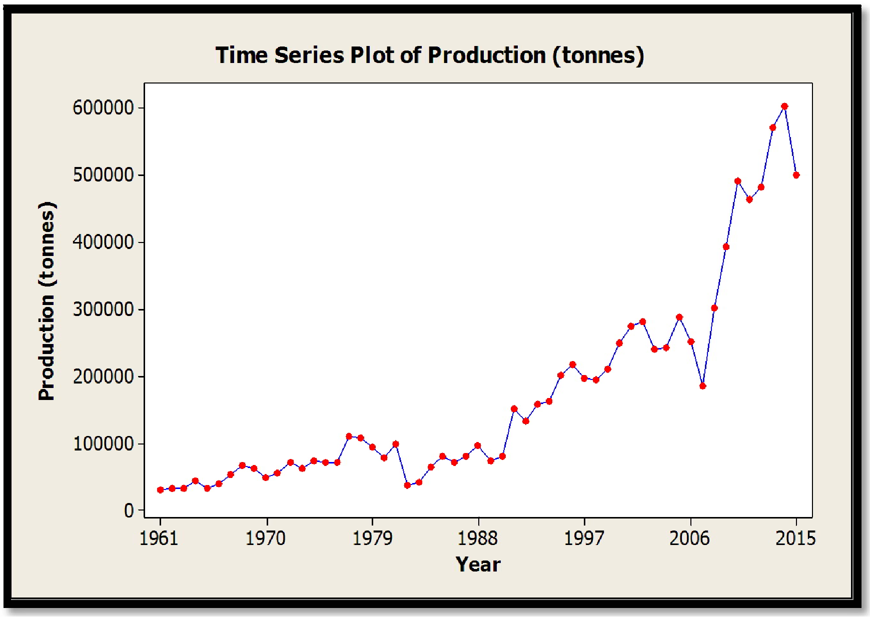

Figure 2: Time Series Plot of Production

The plot in Figure 2 shows the increasing and decreasing pattern of production with respect to time. We observe a generally increasing trend in the plot with a significantly sharp increase between 2008 and 2010. Production however took in significant downward turns in 1982, 2007 and 2015. The generally increasing pattern in the time graph shows a gradual change of the mean and sharper fluctuations over time shows an unstable variance suggesting the series is not stationary.

3.1.3. Trend Analysis

We now fit the general trend models in search of the best to describe the data.

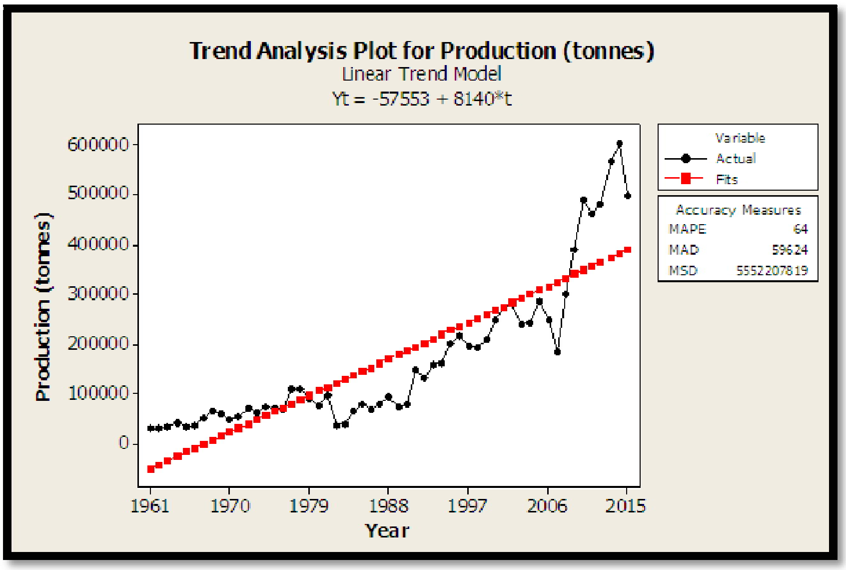

Figure 3: Linear Trend Plot for Paddy Rice Production

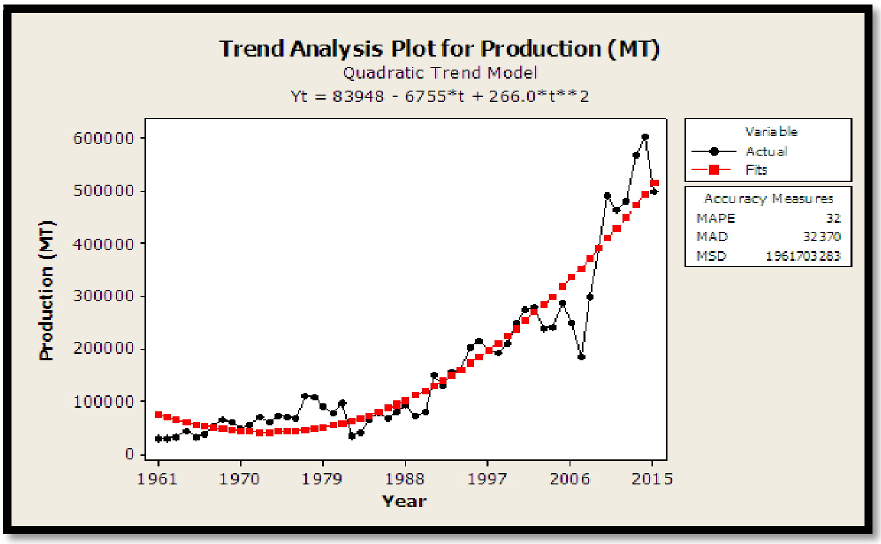

Figure 4: Quadratic Trend Plot for Production

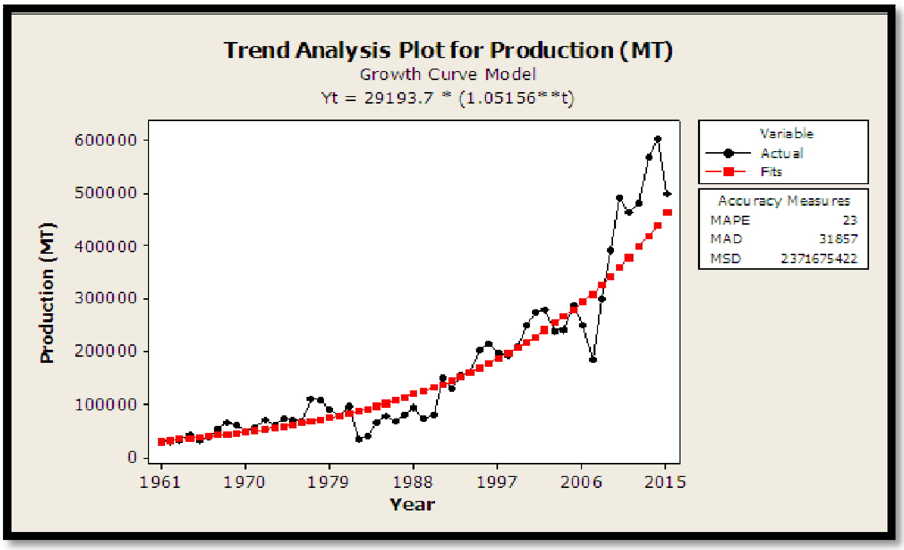

Figure 5: Exponential Trend Plot for Production

Figure 3- Figure 5 shows the linear, quadratic and exponential trend models respectively. The round dotted line represents the actual values of production whereas the square dotted lines represent the fitted values based on the various models.

Model	MAD	MSD	MAPE
Linear	59624	5552207819	64
Quadratic	32370	**1961703283**	32
Exponential	**31857**	2371675422	**23**

Table 3: Measures of Accuracy for Trend in Paddy Rice Production

From Table 3 the most appropriate model to describe the trend in paddy production is the exponential growth model. Considering that the quadratic model has the minimum MSD, the fact that the exponential growth model has the minimum MAD and MAPE is enough to conclude that, the exponential growth model is best in describing the trend in paddy production.

3.2. Further Analysis

3.2.1. Autocorrelation Function (ACF) and Partial Autocorrelation Function (ACF)

A plot of the ACF and PACF of the data in Figure 6 shows that with 95% confidence interval the data appears not stationary, with the ACF dying down slowly and significant spikes at lags 1 and 2 of the PACF.

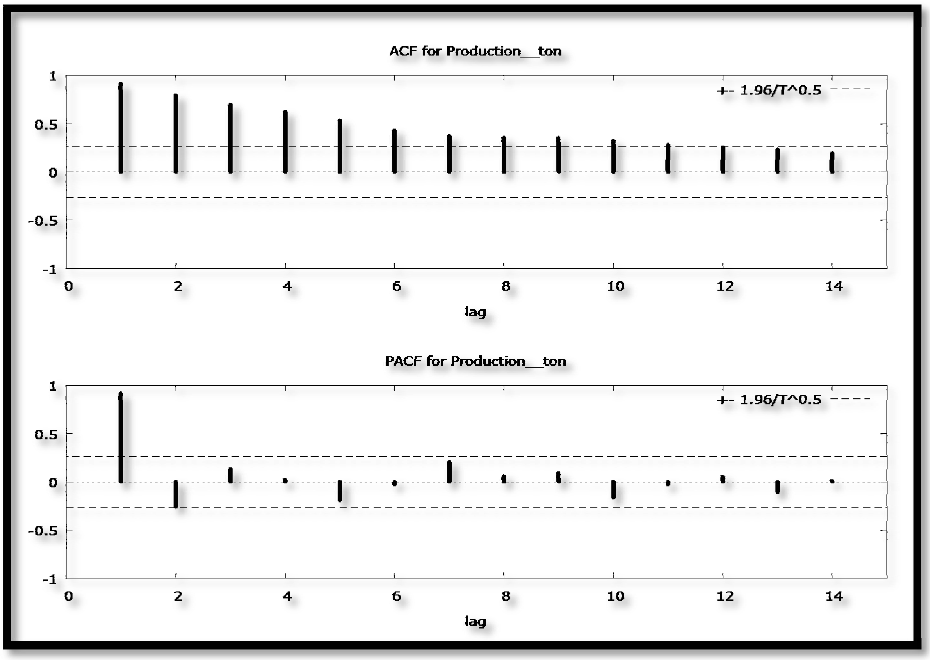

Figure 6: ACF and PACF of Production

3.2.2. Tests for Stationarity

We go ahead to perform Augmented Dickey-Fuller (ADF) test and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test for stationarity.

Test	Test Statistic	P-Value
ADF	3.33849	0.9998
KPSS	1.19383	0.470

Table 4: ADF and KPSS Test for Stationarityof Production

From Table 4, at 5% significance level the KPSS test concludes that the series is not stationary with p-value greater than 0.05, however the ADF test with a reverse null hypothesis concludes that the data is stationary with p-value 0.9998. In all the data is concluded to be non-stationary based on the evidence of the time plot, correlogram and KPSS test, hence needs to be differenced.

3.2.3. Achieving Stationarity

Due to the not stationary nature of the data, it would have to be differenced to obtain stationarity before building any model. For this series that has an exponential growth trend and increasing variance over time we take a logarithm of the data and then difference. A time plot of the transformed data is examined and tested for stationarity.

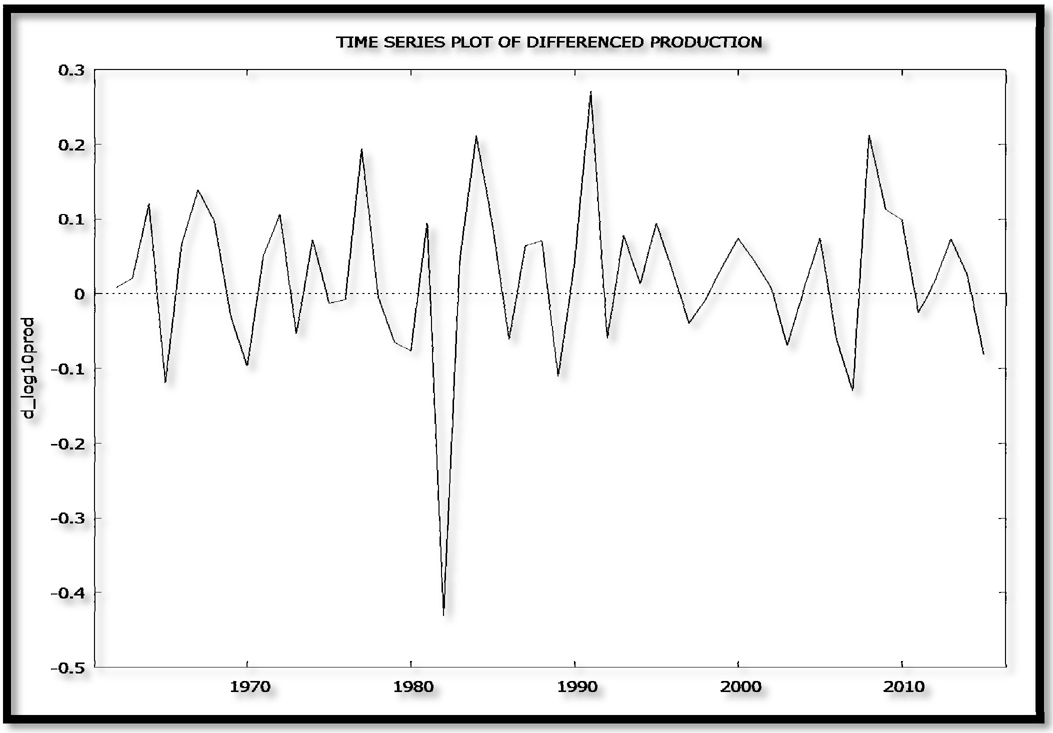

Figure 7: Time Series Plot of Differenced Production

As seen in the Figure 7, the series now fluctuates about the zero point hinting that the series is now of constant mean and variance, indicating stationarity.

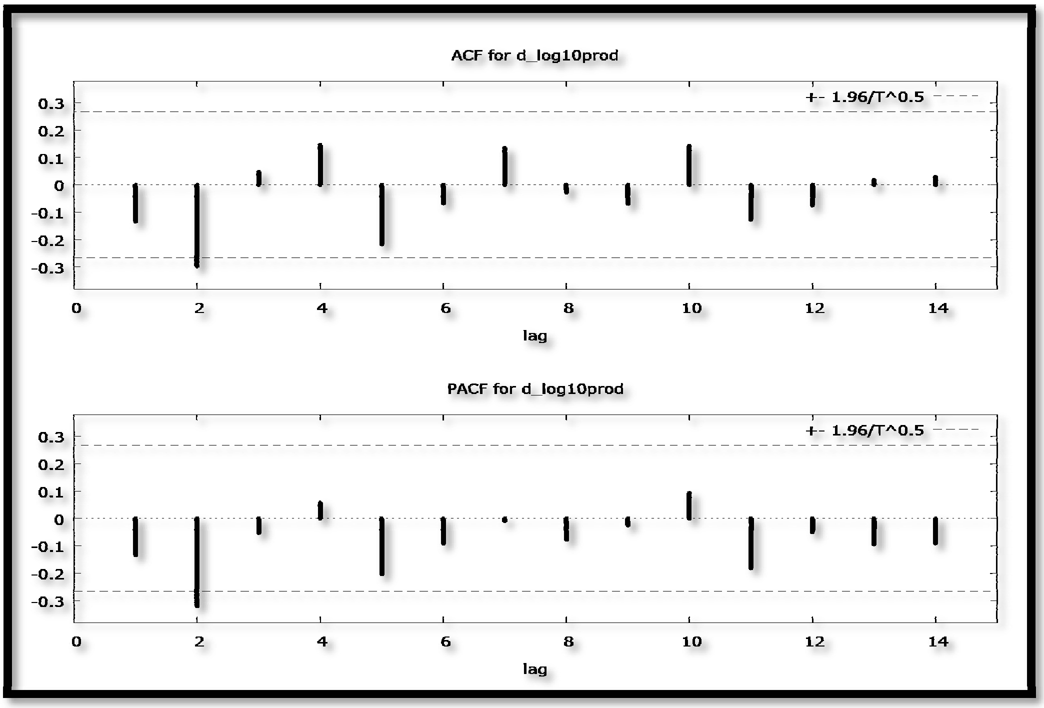

Figure 8: ACF and PACF of the Differenced Production

Figure 8 shows the correlogram of the differenced production data. It shows a rapid decay indicating stationarity. Thestationarity of the differenced data would be confirmed by performing the ADF test and the KPSS test once again. The results in Table 5 show that both tests confirm stationarity after first differencing.

Test	Test Statistic	P-Value
ADF	-7.33344	4.029e-11
KPSS	0.0496	0.470

Table 5: ADF and KPSS Test For Stationarity of Differenced Production

3.2.4. Model Identification

After the series has been made stationary by differencing, the general ARIMA model that best suit the series is the ARIMA (p, 1, q). The next step is to identify which order of p and q best describes the series. The sinusoidal ACF in **Figure 8** with a significant spike at lag 2 suggests MA (2) behaviour. Similarly the significant spikes at lag 2 of the differenced PACF suggest AR (2). Table 6 shows suggested models with their respective AIC and BIC and AIC_C.

Model	AIC	BIC	AIC_C
ARIMA(2, 1, 0)	2.032063	9.988000	2.848390
ARIMA(2, 1, 1)	3.905610	13.85053	5.155610
ARIMA(0, 1, 2)	1.847393	9.803329	2.663720
ARIMA(1, 1, 2)	2.318596	12.26352	3.568596
ARIMA(2, 1, 2)	5.785354	17.71926	7.573188

Table 6: Identified Models and Measures of Accuracy

To select the most appropriate model for our data, we compare all competing models and select the one with the minimum AIC, BIC and AIC_C. From Table 6 it is clear that ARIMA (0, 1, 2) model is the best model for forecasting since it's AIC, BIC and AIC_C values are lower than the other models.

3.2.5. Parameter Estimation

Table 7 displays the estimates of the parameters of the ARIMA (0, 1, 2) model. The MA(2) parameter having a p-value less than 0.05 indicates the significance of the parameters.

Type	Coefficient	Standard error	Z value	P-value
Constant	0.0531796	0.0151232	3.516	0.0004
MA 1	-0.228690	0.131631	-1.737	0.0823
MA 2	-0.300081	0.134965	-2.223	0.0262

Table 7: Parameter Estimates for ARIMA (0, 1, 2)

3.2.6. Model Diagnosis

To ensure that the selected model is the best model that suits the data the following diagnostics are performed.

3.2.6.1. Residuals Plots

The patterns of the residuals over time around the zero mean (**Figure 9**) indicates that the residuals are random and independent of each other making the model fit.

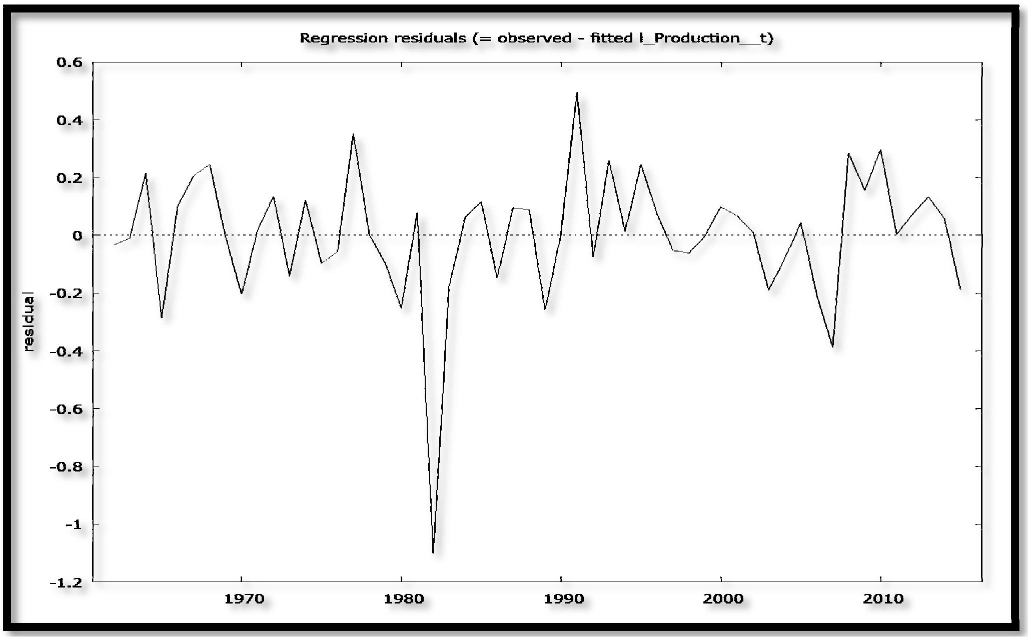

Figure 9: Time Plot of the Residuals

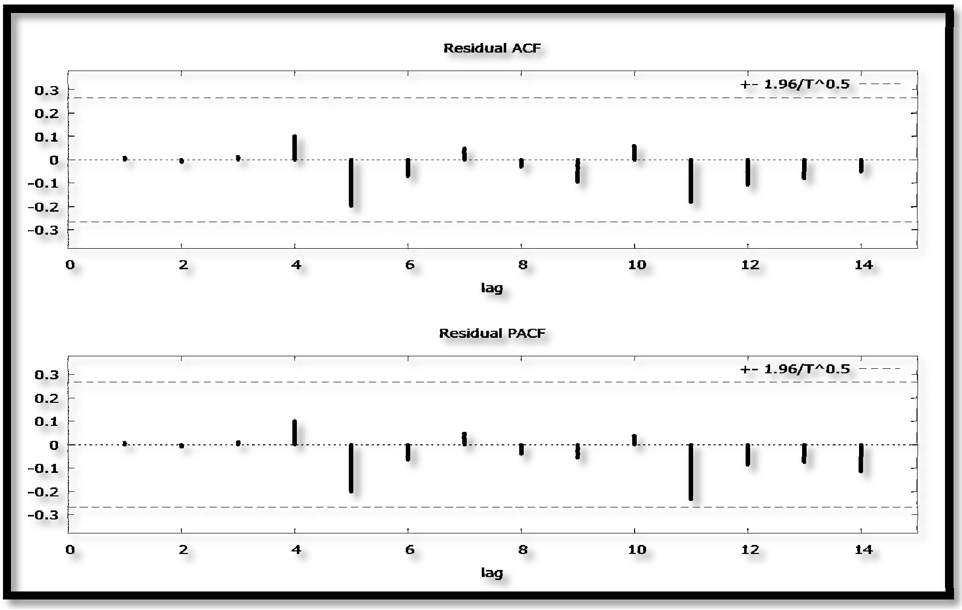

Figure 10: Plot of Residual ACF and PACF

Figure 10 shows all autocorrelation spikes within the 95% confidence interval. This means that there is no correlation between residuals indicating that they are accurate and the model is adequate.

3.2.6.2. The Normal Q-Q Plot

The Q-Q plot in Figure 11shows all points along the normality line except for one outlier hence the model is deemed fit.

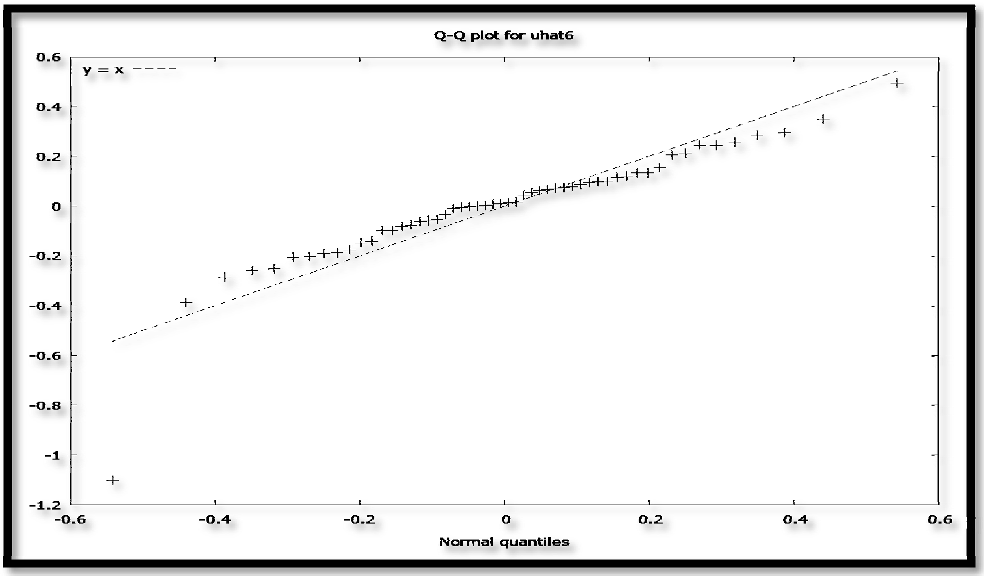

Figure 11: The Normal Q-Q Plot

3.2.6.3.Ljung-Box Q Statistics

A check of the overall model adequacy is made using the Ljung-Box Q statistics. With a p-value of 0.417 which is way greater than 0.05 indicates that the model is generally adequate.

Model	Statistics	DF	Sig.
ARIMA (0, 1, 2)	14.526	16	0.560

Table 8: Ljung-Box Q Statistics

3.2.7. Forecasting

Since the model checks out to be of good fit, we can now forecast for future values in this instance, the next 5 observations.

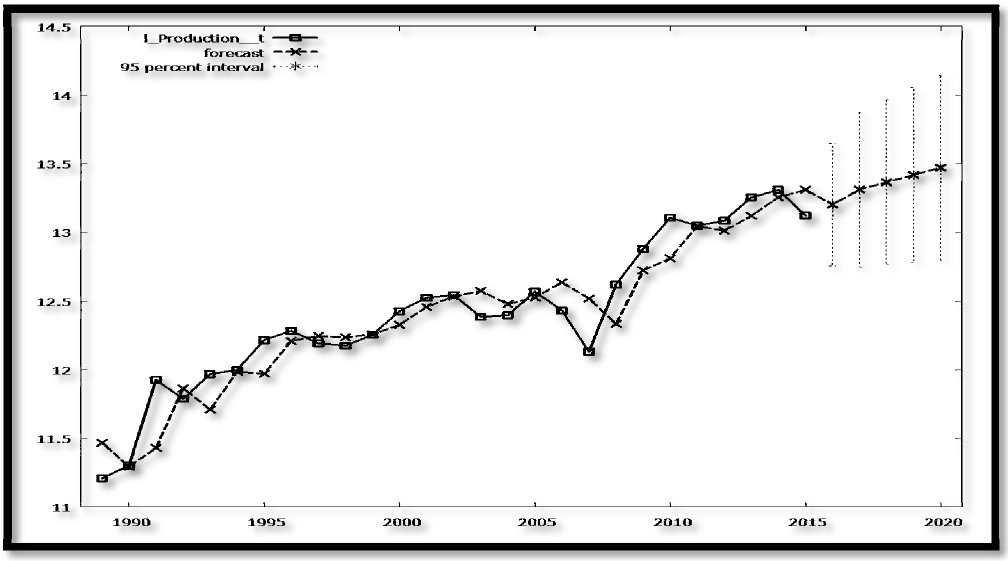

Figure 12: Forecast Plot for Rice Production in Ghana

Year	Forecast(MT)	Lower	Upper
2016	540957.1	430699.5387	679446.6528
2017	603593.9	452617.1936	804935.9596
2018	636561.6	468174.3274	865518.4755
2019	671330.0	484824.8642	929588.2266
2020	707997.4	502553.8111	997434.738

Table 9: Forecast Estimates for Paddy Production

3.3. Results and Discussions

3.3.1. Preliminary Analysis

From the descriptive statistics, in Table 2, it is observed that productions are skewed to the left, indicating that most of the values are concentrated at the left of the mean. The table also shows that the data set is leptokurtic with coefficient of variation less than hundred (100) in nature meaning that the data is peaked and have most of their values dispersed around the centre. Their standard deviations are far away from the mean which indicates volatility.

Figure 2 shows an upward and downward trend with high and low peak indicating an irregular or random trend with the series showing a generally increasing trend.

Figure 3- Figure 5 describe various trend models of the series and the best trend descriptor per the measures of accuracy in Table 3 is the exponential model.

3.3.2. Further Analysis

The series was found not stationary from the ACF and PACF plots. A further test to confirm the stationarity was conducted using the ADF and KPSS test. Hence the data set had to be log-transformed and differenced. The series became stationary upon first differencing.

Table 6 shows the AIC, BIC and AIC_C values compared in the selection of the appropriate model to fit the production series. The best model selected was the ARIMA (0, 1, 2) model.

The model was diagnosed using the Ljung-Box Q statistics, Q-Q plots, and ACF/PACF plot of the residuals and found accurate.

A forecast of production was made based on the selected model for the next five years.

4. Summary and Conclusion of Findings

The research attempted to investigate the trend nature of rice paddy production in Ghana with historic data from1961 to 2015 and hence model for future statistics using the Box-Jenkins methodology of time series analysis.

In the descriptive statistics reading from Table 2, the skewness and kurtosis is positive indicating that most of the values are concentrated on the left of the mean and peaked. Also the data can be best described to follow an exponential growth trend however not stationary and had to be differenced.

The ARIMA (0, 1, 2) model estimated was found accurate and hence forecast made for 2016-2020.

5. Recommendations

Based on the findings of the study, the following are recommended:

- With the exhibition of an exponential growing trend in production, the production-consumption deficit can be eliminated with the right practices and investment.
- From the estimates produced despite the increase in production, it may not be sufficient to meet set targets hence it is recommended that drastic measures be taken to increase production if production targets are to be met.
- The result obtained from this research should serve as a guide to investigate the trend of production. It is further recommended for the model to be reviewed over time and re-estimated when necessary.

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