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# A TIME SERIES ANALYSIS OF AUCTION PRICES OF INDIAN TEA

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## Abstract

*Favorable product prices act as a trigger for any commercial activity over time and also suggest possibilities of sustainability of the activity. Tea is an important commercial crop in India and has been one of the important agricultural export items. Tea industry in the country has gone through phases of many ups and downs, particularly in terms of its export performance during the past. In this paper an analysis of time series data on monthly auction prices of tea has been done to get a deeper insight into the behaviour of tea prices. Monthly auction price data obtained from the Tea Board of India for three years (January, 2012-December, 2014) has been used to analyze the price behaviour. This analysis considered data for two important tea growing regions i.e. north and south India. Overall picture for the country as a whole has also been analyzed in this regard. Autoregressive integrated moving average (ARIMA) model at lag 1 was used for this analysis. The region specific dynamics are distinctly assessed based on the autocorrelation (ACF) and partial autocorrelation (PACF) functions. The possible reasons for the fluctuations in the tea prices have further been analyzed /identified pointing towards the factors of weather conditions, and various production related factors.*

***Keywords:*** *Time series, ARIMA, ACF, PACF, price bahaviour.*

## Introduction

Traditionally, tea has been an important agricultural export item in the country. Presently, India is the second largest producer of tea and fourth largest tea exporting nation (FAO, 2015). However, India tea industry is facing challenges both at production and marketing front. Both domestic and international tea price fluctuations have been the matter of concern for Indian tea industry. The past trends in domestic auction tea prices show a declining trend (Krishnarani, 2013). There were frequent changes in tea prices in the mid 90s to the year 1999, particularly in the prices of South India auction tea prices. On the other hand the North Indian auction prices of tea have also shown an almost constant behaviour. Further, between the years 2000 and 2005 the downward trend with the frequent variations was observed in comparison to the tea prices in late 90s (Sarkar, 2013). Then from the year 2009 to present it is fluctuating consistently and tea auction prices are generally non-stationary in nature (Hettiarachchi & Banneheka, 2013). Hence the present study attempts to identify the variations in Indian tea prices using ARIMA model to study the fluctuations in the data of recent years.

Autoregressive integrated moving average model (ARIMA) or Box-Jenkins model is particularly used to study the market fluctuations, mainly for agricultural commodities. The key benefit of this model is its ability to measure the random variations in a time series. Box-Jenkins time series model is presented in the form: ARIMA (p, d, q). Model identification involves determining the orders (p, d, and q) of the AR (p) and MA (q) components of the model to check the stationarity of the data and to identify the order of differentiation (d), that makes the time series stationary (Kumar & Anand, 2014). The ARIMA (p, d, q) model is represented as;

$$\emptyset(B)\, X_t\, \nabla^d\ X_t = \theta\ (B)\ \varepsilon\ (t)$$

where, $\nabla$ = 1-B, the differencing operator,

$\emptyset$ (B) is the order of p,

$\theta\ (B)$ is of order q,

d is the order of difference.

Four steps are involved in ARIMA modeling: (i) identification (ii) estimation (iii) diagnostics and (iv) validation. The resultant lags of the differenced series in the forecasting equation are called “auto-regressive” terms, lags of the forecast errors are called “moving average” terms, and the time series differenced to make the data stationary is said to be an “integrated” outcome of a stationary data series. The ARIMA model is basically used only for stationary data i.e. the data are in equilibrium around a constant value and that the variance around the mean remains constant over time. The data must be roughly horizontal along time axis. If the mean change over time and variance is not reasonably constant then series is non-stationary which requires the change of the non-stationary tea price data into stationary data; by applying suitable order of differencing to the data series. ARIMA thus helps us to choose “right model” to fit the time series.

## Materials and Methods

The study uses the secondary data collected from the various publications of Tea Board of India. The time series data on monthly auction prices of tea was collected for the time frame of 3 years, from January 2012 to December 2014. ARIMA model was then applied on the collected data to

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study the trend of tea prices for north India (NI), South India (SI) and then overall for all India (AI). The analysis to identify, estimate and diagnose the statistical time series forecasting was done using SPSS 21 software.

Durbin-Watson Test was applied on the collected tea price data to understand the nature of the data and to test the suitability of the data for time series analysis. Durbin-Watson (DW) ≈ 2[1-ρ(1)], where ρ(1) is the auto-correlation with 1st order differencing (Guha & Bandyopadhyay, 2016) was used. The calculated value of the Durbin-Watson test for the data under study was 0.656 which shows that the data is longitudinal and is dependent on time as the computed DW value lies between the acceptance region 0 to 1.5 (Banerjee, 2014). Thus it was found that the time series analysis can be applied on the data.

## Results and Discussion

Results of the time series analysis on non-stationary Indian tea auction price using the lagged autocorrelation version of time series analysis are presented and discussed hereunder.

### 1. Time Series Analysis of Tea Price

Time series plots of the three types of data presented individually (Fig. 1 to 3) and also compiled together (Fig. 4) revealed the non-stationary behaviour of data with the upward trend for North India and a downward trend for South India for the total of 36 months of time period considered in the study.

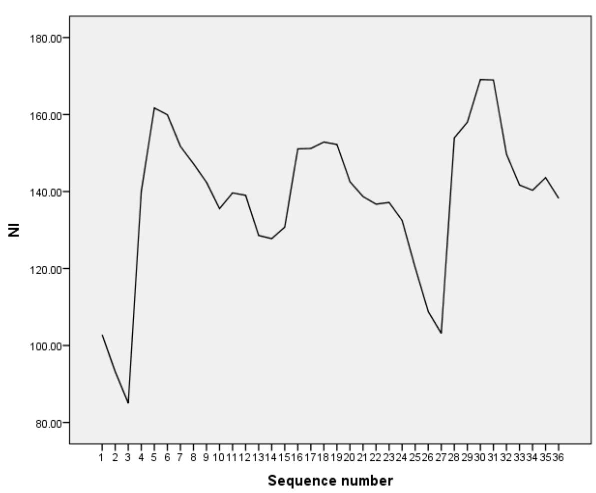


**Fig. 1:** Time series plotting of North India

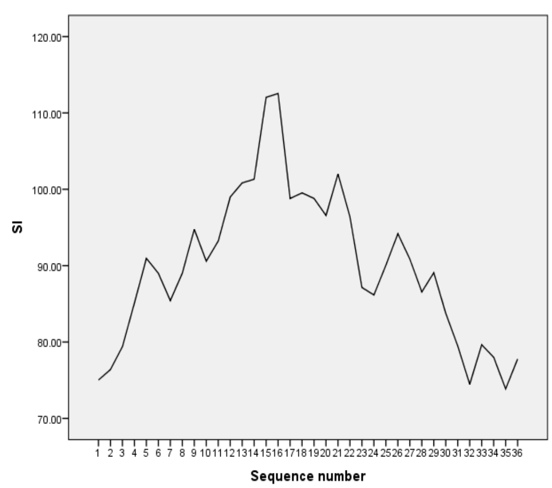


**Fig. 2:** Time series plotting of South India

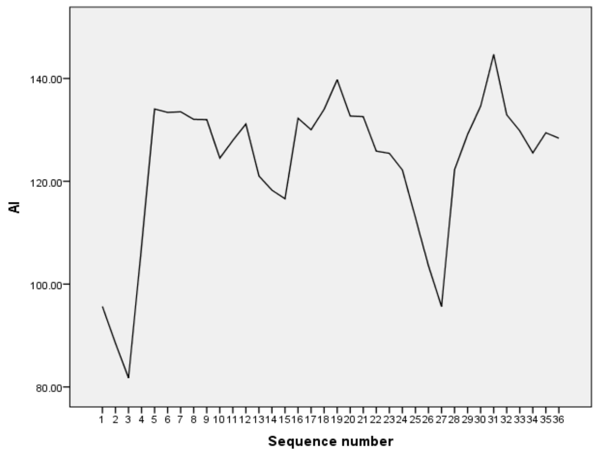


**Fig. 3:** Time series plotting of All India

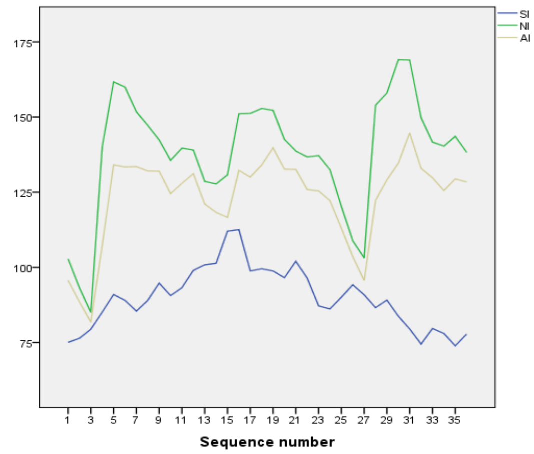


**Fig. 4:** Time series plotting of all three regions

## 2. Autocorrelation Analysis

For autocorrelation analysis, to make the data stationary suitable differences were applied to create new stationary series. The functions used to identify the model parameters are autocorrelation function (ACF) and partial autocorrelation function (PACF). Autocorrelation function shows the correlation between time series ($X_t$) and the same time series lag ($X_{t+k}$). The partial autocorrelation function shows the degree of association between the basic time series ($X_t$) and the same time series lag ($X_{t+k}$). The ACF and PACF correlogram are plotted to identify the ARIMA model at 16 lags.

The time series plot of the North India data shows the non-stationary series. The ACF (NI) for North India (Fig. 5) shows the wavy graph with highly significant values at lags 1, 4, 5 and 12. PACF (NI) (Fig. 6) is significant at lag 12. This highlights the need of differencing of the data. After differencing the data by order 1, the ACF (NI) (Fig. 7) and PACF (NI) (Fig. 8) correlogram are plotted. The differenced data shows significant ACF (NI) at lags 1, and 2 and PACF (NI) shows the data falling within the limit with no significant lags. The comparative scrutiny of the differenced and non-differenced correlograms shows the extreme price fluctuations from Rs. 84.99 in March 2012 to Rs. 169.08 in June 2014; with the lowest auction price of Rs.103.14 in March 2014 after Rs. 84.99 in March 2012. At lag 12 i.e. in January 2014 the fluctuations still exist. This could be the result of tea development and promotional schemes of the government. These schemes were aimed at improving tea quality, increasing tea production and productivity. The schemes also targeted the focused tea promotional campaigns both domestically and internationally for accelerating the realisation of higher unit value for Indian tea.

The ARIMA (1, 0, 1) model was applied and the normalized BIC value (Table 1) was calculated. The plots of the ACF (NI) and the PACF (NI) of the residuals (Fig. 9) show that the values fall within the given confidence intervals. The estimate of the model parameters are given in Table 1 and testing of the significance of the model parameters is also done thus presenting the results of the fitted model.

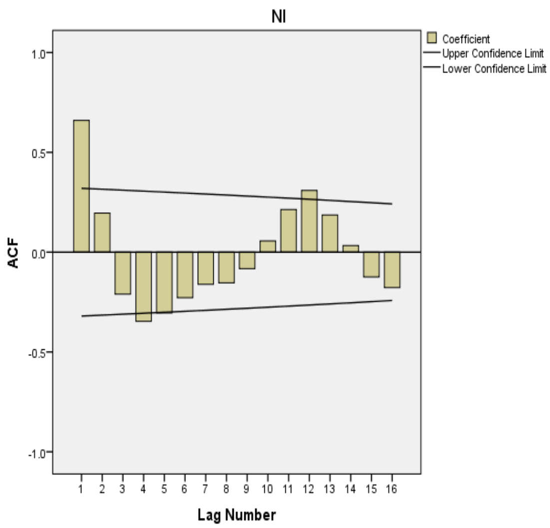


**Fig. 5:** ACF (NI) of North India

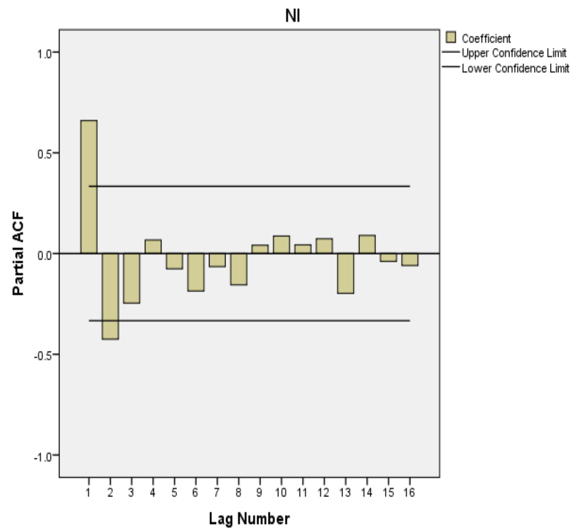


**Fig. 6:** PACF (NI) of North India

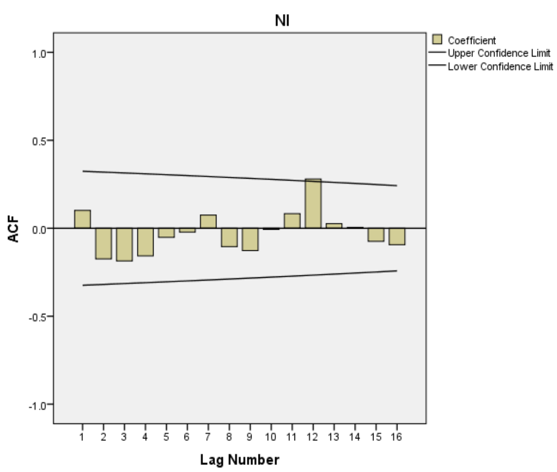


**Fig. 7:** ACF (NI) of differenced series

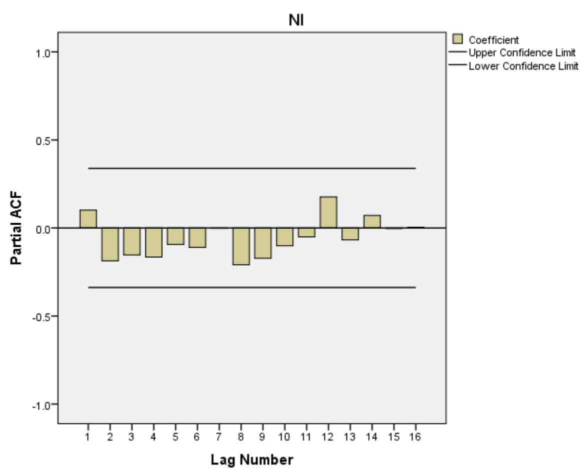


**Fig. 8:** PACF (NI) of differenced series

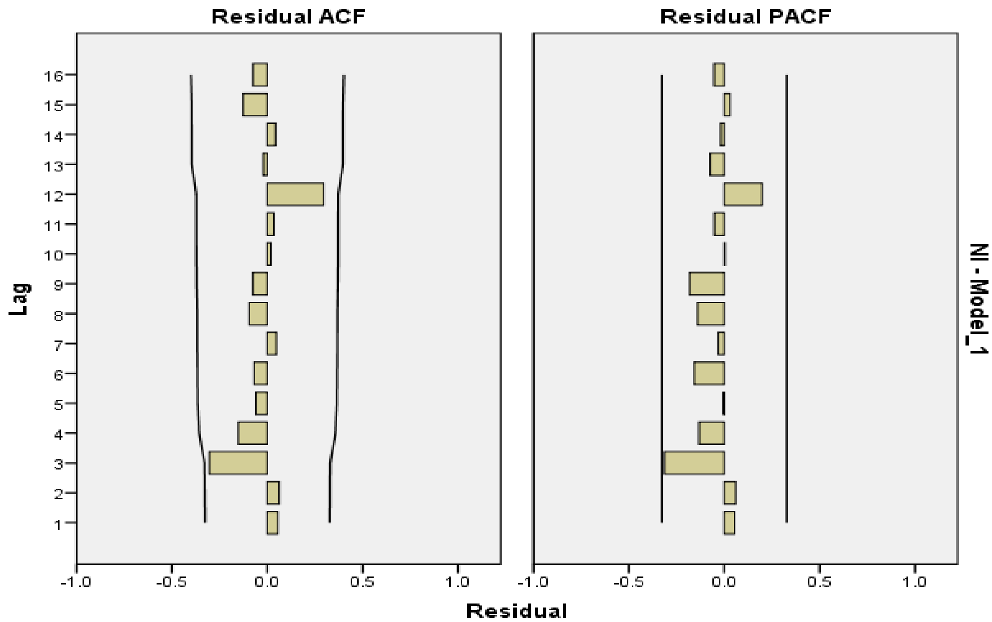


**Fig. 9:** ACF and PACF of the residuals (North India)

**Table 1: Estimates of the model parameters for North India**

| Type | Estimates | S.E. | t value | p-value |
|---|---|---|---|---|
| Constant | 139.517 | 1.534 | 90.921 | 0 |
| AR(1) | 0.274 | 2.749 | 0.1 | 0.992 |
| MA(1) | -0.325 | 43.343 | -0.007 | 0.994 |
| Normalized BIC value for ARIMA (1, 0, 1) | 5.665 | | | |
| Fitted Model | $X_1 = 139.517 + 0.274\ X_{t-1} - 0.216\ X_{t-12} + e_t$ | | | |

Now looking into the data for South India, ACF (SI) shows a downward falling curve, significant at lag 1, 2, 3, 4, 5, 12, 13, 14, 15 and 16 (Fig. 10) and PACF (SI) is significant at lag 1 only (Fig. 11). After differencing the data the ACF (SI) and PACF (SI) were found to be significant at lag 2 only. At lag 2 i.e. in November 2014, fluctuations still exist in the prices of South Indian tea which is mainly the result of the falling production level of tea due to extreme weather conditions (Anil, 2014), and increasing cost of production. The residuals of ACF (SI) and the PACF (SI) show the significant and suitable data set. The model parameters Using ARIMA (1, 0, 1) model are presented in Table 2.

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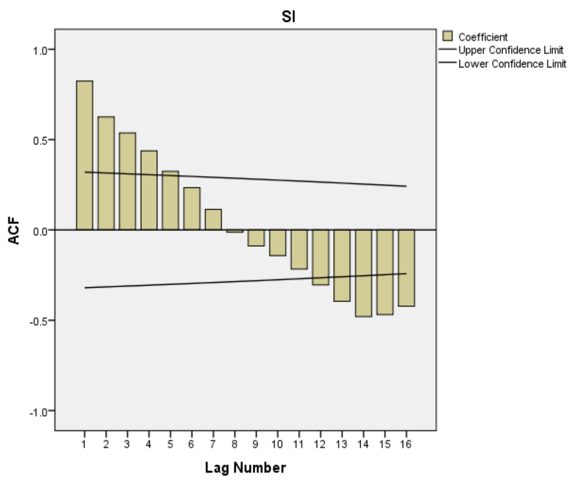


**Fig. 10:** ACF (SI) of South India

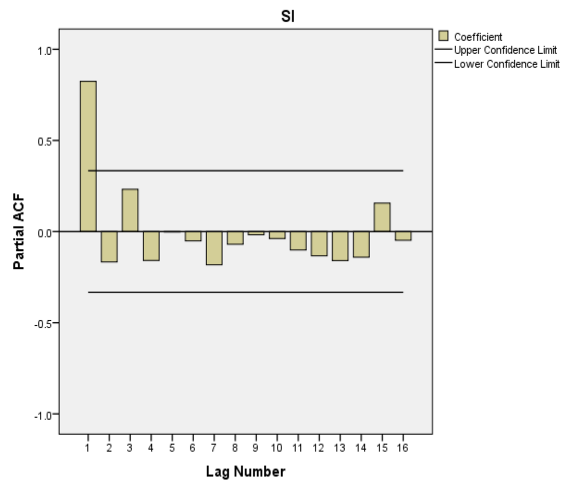


**Fig. 11:** PACF (SI) of South India

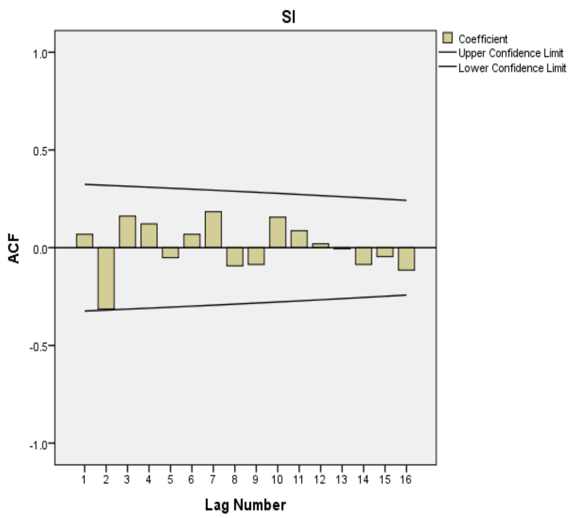


**Fig. 12:** ACF (SI) of differenced series of South India

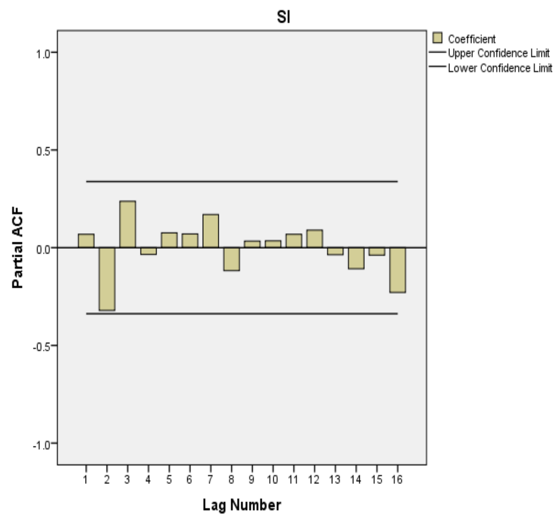


**Fig. 13:** PACF (SI) of differenced series of South India

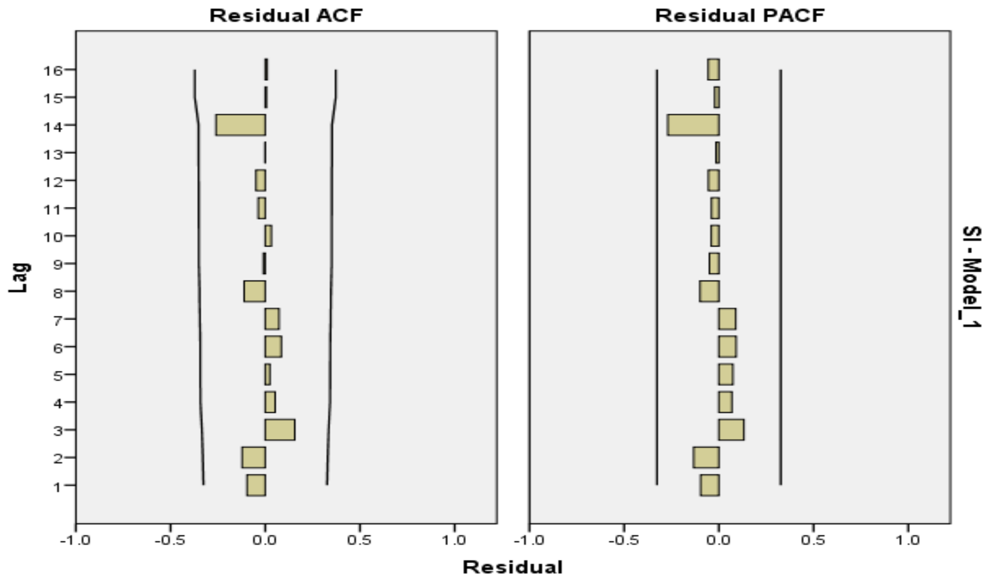


**Fig. 14:** ACF and PACF of the residuals (South India)

**Table 2: Estimates of the model parameters for South India**

| Type | Estimate s | S.E. | t value | p- value |
|---|---|---|---|---|
| Constant | 89.360 | 2.942 | 30.36 9 | 0.00 0 |
| AR(1) | 0.782 | 0.378 | 2.069 | 0.05 0 |
| MA(1) | -0.407 | 880.66 3 | 0.000 | 1.00 0 |
| Normalized BIC value for ARIMA(1, 0, 1) | 3.602 | | | |
| Fitted Model | $X_2 = 89.360 + 0.782\ X_{t-1} + 0.454\ X_{t-12} + e_t$ | | | |

Finally, the All India data were analyzed. The ACF (AI) shows a wave-like pattern significant at lags 1, 2, 5, 6 and 12 (Fig. 15) and PACF is significant at lags 1 and 2 (Fig. 16) which means that seasonal AR and MA terms are needed to model the data. First order differencing shows ACF (AI) high at lag 12 (Fig. 17) and PACF (AI) at lag 8 (Fig. 18). Outcome of the ARIMA model (1, 0, 1), the normalized BIC values and the model fit are computed and shown in the Table 3. The ACF (AI) and PACF (AI) of the residuals support the suitability of the model (Fig. 19). The significant value at lag 12 i.e. in January 2014 marked the fluctuations in the All India auction data, the reasons are explained in the case of North and South Indian Tea Price fluctuations.

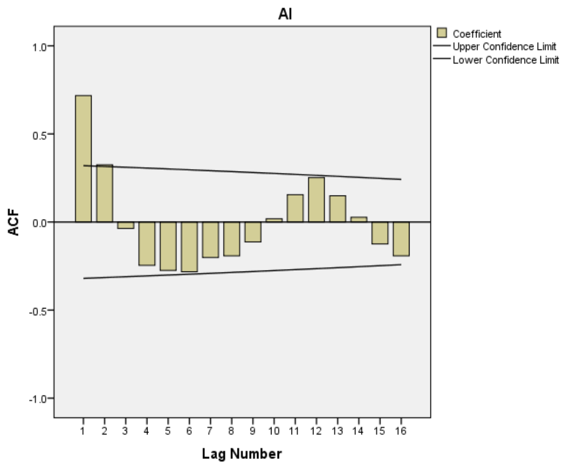


**Fig. 15:** ACF (AI) of All India

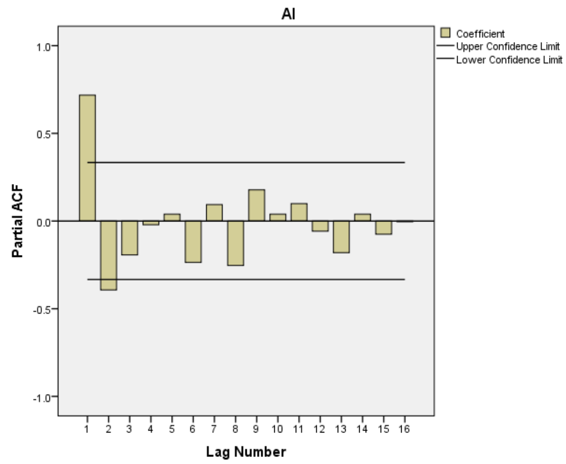


**Fig. 16:** PACF (AI) of All India

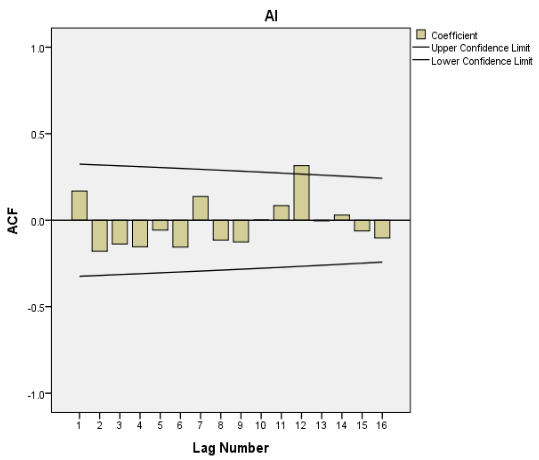


**Fig. 17:** ACF (AI) of differenced series of All India

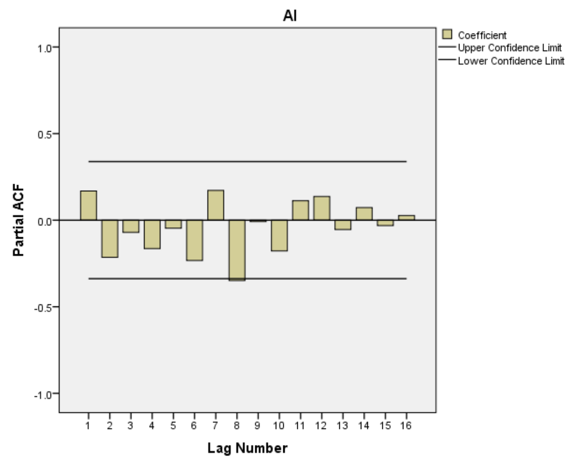


**Fig. 18:** PACF (AI) of differenced series of All India

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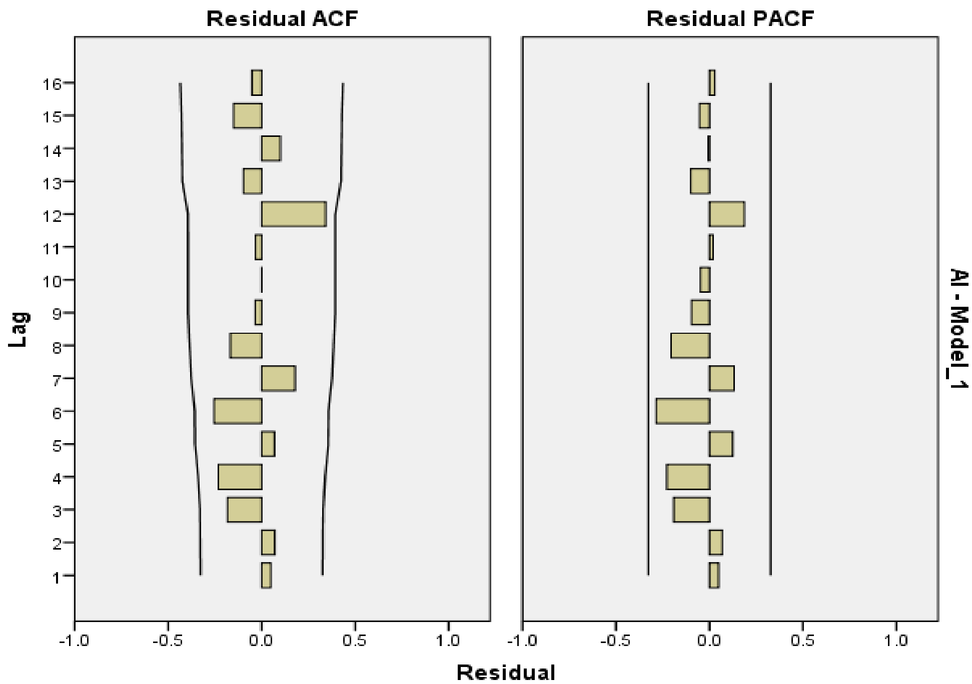


**Fig. 19:** ACF and PACF of the residuals (All India)

**Table 3: Estimates of the model parameters for All India**

| Type | Estimates | S.E. | t value | p-value |
|---|---|---|---|---|
| Constant | 124.927 | 1.442 | 86.652 | 0.000 |
| AR(1) | 0.555 | 0.954 | 0.582 | 0.566 |
| MA(1) | -0.483 | 320.898 | -0.002 | 0.999 |
| Normalized BIC value for ARIMA(1, 0, 1) | 4.885 | | | |
| Fitted Model | $X_3 = 76.389 + 0.992 X_{t-1} - 0.320 X_{t-12} + e_t$ | | | |

The adequacy of the model fit in the three cases was detected by considering the residuals. The estimated autocorrelation function (ACF) and partial autocorrelation (PACF) function of the fitted models is falling within the upper and lower bounds.

## Conclusion

The model fitting for the north, south and all India tea auction price data was done using ARIMA (1, 0, 1). The fluctuations in auction price data of three years noticed and the major reasons for these fluctuations, also on the basis of past research were identified as (i) the decline in production due to drought like conditions, pest attacks, and inconsistent weather conditions (ii) increasing labour and other components of cost of production The north and south India tea prices also showed major gap and fluctuations in tea prices. This is mainly ascribed to the fact that southern CTC tea is relatively of lower quality as compared to that of north India and that there are a large number of small growers in southern region (Tea Board, 2000; 2003) which further influences production cost and also the production.

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