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MODEL SELECTION IN DESCRIPTIVE TIME SERIES: A PARAMETRIC AND NON-PARAMETRIC PERSPECTIVE

Joy Ifechukwu Nnadi

Department of Mathematics/Statistics,  
University of Port Harcourt, Port Harcourt,  
Nigeria  
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**Abstract:** In this paper, we investigated the choice between additive and multiplicative models using statistical test in time series decomposition. The Buys-Ballot procedure was adopted and two parametric and one non parametric test for constant variance were applied to the column variance of the Buys-Ballot table. The results of the illustrative examples using the monthly demand data of Abeokuta base Danico food limited showed that the parametric (Bartlett and Hartley) and non-parametric (Square Rank) were significant at 5% level indicating that the appropriate model for decomposition is the additive model. Also the application of the same test to quarterly data of the price of square meter of housing in Spain from January 1987 until October 2003 show that the respective statistic were less than their corresponding critical level at 1% significant level indicating that the appropriated model for decomposition of the series is the multiplicative model.

**Keywords:** Descriptive time series, trend, seasonality, choice of model, additive model, multiplicative model .

Introduction

Choice of model plays an important role in descriptive time series as it help to facilitate forecasting. Two patterns that may be presented in the identification of time series data are trend and seasonality and the two competing models are the additive and multiplicative models (Iwueze and Nwogu, 2014). Descriptive time series is the separation of the observe time series into four components represented by the trend ( $T_t$ ), seasonal ( $S_t$ ), cyclical ( $C_t$ ) and the irregular ( $e_t$ ) components. One of the advantages for decomposition in descriptive time series is to estimate seasonal effect that can be used to create and present seasonally adjusted values.

Decomposition models are typically additive or multiplicative, but can also take other forms such as pseudo-additive. The cyclical component is embedded in the trend for short series (Chatfield, 2004). These models are;

Additive Model:

$$X_t = M_t + S_t + e_t \tag{1}$$

Multiplicative Model:

$$X_t = M_t \times S_t \times e_t \tag{2}$$

Pseudo-Additive:

$$X_t = M_t + S_t \times e_t \tag{3}$$

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where  $M_t$  is the trend-cycle component;  $S_t$  is the seasonal component and  $e_t$  is the irregular component. For the additive model (1), it is assumed that the error component  $e_t$  is the Gaussian white noise  $N(0, \sigma_1^2)$  and the sum of the seasonal component over a complete

period is zero  $\sum_{j=0}^{s-1} S_j = 0$ . While for the multiplicative model (2),  $e_t$  is the Gaussian white

noise  $N(1, \sigma_2^2)$  and the sum of the seasonal component over a complete period is  $s$

$$\sum_{j=0}^{s-1} S_j = s$$

$$\sum_{j=0}^{s-1} S_j = 1$$

An important part of the analysis of descriptive time series is the selection of a suitable model for decomposition. The graphical method and non-graphical method has been proposed in the literature to aid the choice of model between additive and multiplicative models. Brockwell and Davis (2002), use the time plot of the entire series to choose a particular model for decomposition. The multiplicative model was adopted when the magnitude of the seasonal pattern in the data depends on the magnitude of the series. In other words, the magnitude of the seasonal pattern increases as the data value increases and decreases as the data value decreases. The additive model was adopted when the magnitude of the seasonal pattern does not change as the series goes up and down. Chatfield (2004) noted that if the seasonal variation stays roughly the same size regardless of the mean level, then it is additive but if it increases in size in direct proportion to the mean level, the appropriate model for decomposition is the multiplicative models. However, there are situations when such plots are not easy to interpret and as such choosing between additive and multiplicative model becomes difficult. Instead of using the seasonal pattern as shown by the time series plot of the entire series, Iwueze et al (2011) used the relationship between the plot of the seasonal means and seasonal standard deviation derived from the Buys-Ballot Table (see Table 1) to choose between additive and multiplicative models.

The aim of this paper is to provide a test that will aid in the choice between additive and multiplicative models in time series decomposition. The rational for this paper is that most existing methods are subjective and tedious. Hence, the need for simpler method and statistical to ascertain the need to choose between both models

**Table 1.0:** Buys-Ballot Table

Period( $i$ )	Seasons								
	1	2	...	j	...	s	$T_i$	$X_i$	$\hat{\sigma}_i$
1	$X_1$	$X_2$	...	$X_j$	...	$X_s$	$T_1$	$X_1$	$\hat{\sigma}_1$
2	$X_{s+1}$	$X_{s+2}$	...	$X_{s+j}$	...	$X_{2s}$	$T_2$	$X_2$	$\hat{\sigma}_2$
3	$X_{2s+1}$	$X_{2s+2}$	...	$X_{2s+j}$	...	$X_{3s}$	$T_3$	$X_3$	$\hat{\sigma}_3$
...	...	...	...	...	...	...	...	...	...
$i$	$X_{(i-1)s+1}$	$X_{(i-1)s+2}$	...	$X_{(i-1)s+j}$	...	$X_{(i-1)s+s}$	$T_i$	$X_i$	$\hat{\sigma}_i$

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...	...	...	...	...	...	...	...	...	...
$m$	$X_{(m-1)s+1}$	$X_{(m-1)s+2}$	...	$X_{(m-1)s+j}$	...	$X_{ms}$	$T_m$	$X_m$	$\sigma^2_m$
$T_j$	$T_{.1}$	$T_{.2}$	...	$T_{.j}$	...	$T_{.s}$	$T_{..}$	-	-
$X_{.j}$	$X_{.1}$	$X_{.2}$	...	$X_{.j}$	...	$X_{.s}$	-	$X_{..}$	
$\sigma^2_{.j}$	$\sigma^2_{.1}$	$\sigma^2_{.2}$	...	$\sigma^2_{.j}$	...	$\sigma^2_{.s}$	-	-	$\sigma^2_{..}$

**Source:** Iwueze and Nwogu (2014) where  $X_{ij} = X_{(i-1)s+j}$ ,  $i = 1, 2, \dots, m$ ,  $j = 1, 2, \dots, s$  is the series,  $m$  is the number of periods/years,  $s$  is the periodicity, and  $n = ms$  is the overall number of observation/sample size.

$T_j$  Total for  $j$ th season,  $X_{.j}$  Average of  $j$ th season  $\sigma^2_{.j}$  Standard deviation for  $j$ th season.

Column averages and standard deviation is defined as follows:

$$\bar{X}_{.j} = \frac{1}{m} \sum_{i=1}^m X_{(i-1)s+j}, j = 1, 2, \dots, s$$

$$\sigma^2_{.j} = \frac{1}{m} \sum_{i=1}^m (X_{(i-1)s+j} - \bar{X}_{.j})^2, j = 1, 2, \dots, s$$

$\sigma^2_{i1}$

## 2 Methodology

This paper will adopt the method of comparison of seasonal/column variances of the Buys-Ballot Table proposed by Iwueze and Nwogu (2014) with the inclusion of error component in the derivation of column mean and variances as this was ignored in Iwueze and Nwogu (2014) derivation of the column mean and variance. With the use of the Buys-Ballot Table, the problem of choice between additive and multiplicative models reduces to test for constant variance in the column variances. Table 2 below shows the summary of the result of the derivation of the column variance and mean when trend-cycle component is linear.

**Table 2: Row, Column Totals, Averages and Variances of Buys-Ballot for Additive and Multiplicative Models**

	Linear trend-cycle component: $M_t = a + bt$ , $t = 1, 2, \dots, n$ $n = sm$	
	Additive Model	Multiplicative Model
$X_j$	$a + \frac{bs}{2} (m-1) + bj + S_j + e_j$	$a + \frac{bs}{2} m$ $a + e_j + m(i-1)e_{ij} + bs e_j + bj e_j + S_j$
$\sigma^2_{.j}$	$\frac{2}{b} \left[ \frac{n(n-1)s}{6} + \frac{2}{3} \right]$ $\frac{1}{12} \left[ \frac{n(n-1)s}{6} + \frac{2}{3} \right]$	$\frac{b^2}{12} \left[ \frac{n(n-1)s}{6} + \frac{2}{3} \right]$ $\frac{1}{12} \left[ \frac{n(n-1)s}{6} + \frac{2}{3} \right]$

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$$b^2 \leq n(n + s) \leq 2n^2, \text{ for additive model}$$

$$\begin{array}{ccccccc} & & \overline{\phantom{0}} & & & & \\ & \square & \square & 12 & \square & & \\ \square^2_{\cdot j} \square & \square & & & & & \end{array} \quad (4)$$

$$b^2_{\alpha\beta} = n^{-2} 12 s_2 \alpha_{\beta} \alpha_{\gamma} \alpha_{\delta} j_{\gamma\delta}^2 \alpha_{\alpha} * \alpha^{-2} S_j^2, \text{ for multiplicative model}$$

$$\sum_{k=1}^K \log S_p^2 + \sum_{i=1}^{n_i} \log S_i^2$$

$$G \square \frac{i \square 1}{1 \square \frac{1}{\square} \square^k \square \frac{1}{\square} \square \frac{1}{\square} \square} \quad (6)$$

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$$S_p^2 = \frac{1}{N} \sum_{i=1}^N S_i^2 \quad (7)$$

where

Using the Buys –Ballot technique where  $n_i = m$ ,  $k = s$ ,  $N = ms$ , Equation (6) can be written as

$$G = \frac{\sum_{j=1}^s \sum_{i=1}^m S_{ij}^2}{\sum_{j=1}^s \sum_{i=1}^m S_{ij}^2} \quad (8)$$

where

$S_j^2$  is the column sample variances from the  $j$ th sample, 2.3026 is a constant value,  $m$  is the sample size of  $j$ th group,  $s$  is the number of groups. The null hypothesis is rejected if the statistic (5) is greater than the tabulated Chi-Square value or not rejected otherwise.

### b. Hartley's Test

The Hartley's  $F_{\max}$  utilizes only the highest and lowest variances of the groups. The statistic makes do with the Hartley  $F_{\max}$  table with  $s$  and  $m-1$  degree of freedom. The test is defined as

$$F = \frac{\max(S_j^2)}{\min(S_j^2)}$$

(9) where,

$S_j^2$  = column variance of the  $j$ th group,  $j=1,2,...,s$

$S_j^2(\max) = \max(S_1^2, S_2^2, ..., S_s^2)$ ,  $S_j^2(\min) = \min(S_1^2, S_2^2, ..., S_s^2)$

$s$  = number of groups,  $m$  = sample size of  $j$ th group

The null hypothesis is rejected if the calculated statistic (9) is greater than the  $F_{\max}$  table critical value with  $s$  and  $m-1$  degree of freedom, (Hartley, 1950).

### Square Rank Test

The Square rank test also known as Conover test is a non-parametric test for either the two sample case or the case of  $k$  group, (Conover, 1999).

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$$X_{ij} = Y_{ij} - \bar{Y}_{.j}$$

The test statistic is define as

$$T = \frac{1}{2} \sum_{i=1}^k \frac{s_i^2}{n_i} - \frac{1}{2} \sum_{j=1}^2 \frac{NR_{2j}^2}{n_j} \quad (10)$$

where,

$s_i$  is sum of square ranks in subsample  $i$ ,  $n_i$  is number of observations in subsample  $i$   $Y_{ij}$  is the original series,  $\bar{Y}_{.j}$  is the column mean and  $X_{ij}$  is the new ranked series

$$P_2 = \frac{1}{N} \sum_{i=1}^N R_i^2 - \frac{1}{N} \sum_{j=1}^2 \frac{R_{2j}^2}{n_j} \quad (11)$$

$R_i$  rank of observation  $i$

If there are no ties in the Rank like the Buys-Ballot Table, then the test statistic is given by

$$T = \frac{5}{36} \sum_{j=1}^m S_j^2 - \frac{mn(n-1)^2(2n-1)^2}{(n-1)^2(2n-1)^2} \quad (12)$$

Where  $n$  is the total sample size of the series,  $m$  is the sample size of the  $j$ th subgroup and  $S_j$  is the sum of square rank of the  $j$ th group. If the assumptions are met, the distribution of this test statistic (12) follows approximately the chi-square distribution with  $k-1$  degree of freedom.

### 3. Empirical Examples

The Results of the monthly demand of Abeokuta base Danico foods limited from (2002-2009) for the computed column variances of the Buys-Ballot table for the parametric and nonparametric test for constant variance are shown in Table 3

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Table 3: Test Statistic for parametric and non-parametric test of Abeokuta Danico food limited

Level of Significance	Test Statistics		
	Bartlett	Hartley	Square Rank
Calculated Statistic	11.09	5.791	6.78
Critical value at 5%	19.675	15.80	19.675

Bartlett ,Square Rank ( $\chi^2_{11}(0.05)$ )  $\square$  19.675 ,Hartley( $F_{\max (12,7)}$ ) $\square$  15.8

**Remark:** The results in Table 3 show that all calculated test statistic lies within the respective critical values indicating that the null hypothesis is accepted and the model for decomposition of the monthly demand of Abeokuta base Danico foods limited is the additive model.

Table 4: Test Statistic for parametric and non-parametric test of Average price of square meter of housing in Spain

Level of Significance	Test Statistics		
	Bartlett	Hartley	Square Rank
Calculated Statistic	10.09	15.79	16.78
Critical value at 5%	7.81	4.98	7.81

Bartlett ,Square Rank ( $\chi^2_3(0.05)$ )  $\square$  7.81 ,Hartley( $F_{\max (4,17)}$ ) $\square$  4.98

**Remark:** The results in Table 4 show that all calculated test statistic were greater than their respective critical values indicating that the null hypothesis is accepted and the model for decomposition of the price of housing in Spain is the multiplicative

4. Conclusion

It is important to check the features of the data before appropriate model is chosen for decomposition. The selection of an adequate model is very important as it shows the underlying structure of the series because the fitted model will be used for future forecasting. The illustrative examples shows that the additive model should be used to decompose the monthly sales of Abeokuta Danico food limited and the multiplicative model should be used to decompose the average price housing of Spain. the parametric (Bartlett and Hartley) and the Square Rank non parametric test can be used to justify the choice of model using the Buys-Ballot procedure.

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