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Buys Ballot Approach in Time Series Analysis of Typhoid Fever

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Abstract: Typhoid fever (is also called enteric fever) is a bacterial disease spread through contaminated food, water or close contact. However, where it is prevalence government usually recommend vaccines to curtail its deadly spreading in the affected area. The fever is caused by Salmonella typhi bacteria. Therefore, we had adopted the Buys Ballot approach by using time series analysis for the estimation of trend of typhoid fever disease from the year 2011 to 2020 and predicts the future occurrence of the disease in Mubi South Local Government Area (LGA) of Adamawa State, Nigeria. However, based on the data used the result shows that there is significant increase in the recorded cases of typhoid fever disease, it has forecasted and predicted that more number of people may be affected in future compared to the study results obtained. Hence, this study has given some recommendations in order to reduce the prevalence of typhoid fever disease in future.

Keywords: Analysis; Anorexia; Salmonella Typhi; Prevalence; Trend.

Introduction

Typhoid Fever is a life threatening infection caused by the bacterium salmonella typhi. It is usually spread through contaminated food and water. The World Health Organization (WHO, 2018), estimated that about 11-12 million people get sick from typhoid and between 128,000 and 161,000 people die from it every year. Typhoid fever is a systematic disease caused by dissemination of salmonella Typhi or salmonella paratyphi mainly characterized by fever. It was called Typhoid Fever because of its common similarity to typhus. It was clearly defined pathologically as a unique disease of its own, it is a common worldwide illness, transmitted by the ingestion of food or water contaminated with the faeces of an infected person, which contain the bacterium salmonella enterica. The bacteria then perforate through the intestinal wall and are phagocyte by macrophages.

According to medical dictionary (Budelka, 2015), which reveals that typhoid fever as an infection which is usually spread by contamination of food, milk or water supply with salmonella typhi (S. typhi), either directly by sewage or indirectly by flies or by faulty personal hygiene. Symptomless carries harbouring the germ in the gall bladder and excreting it in their stools are the main sources of out breaks of disease in this country. The average incubation period is 10-14 days. A progressive febrile illness marks the onset of disease which develops as the germ invades typhoid tissues, including that of the small intestine (peyer`s patches) to profuse diarrhoea (pea soup) stools which may become frankly haemorrhagic, ultimate recovery usually begins at the end of the third week. A rose coloured rash may appear on the upper abdomen and back at the end of the first week.

Over the last decade, there has been alarming increase in the rate of recorded cases of typhoid fever in our various hospitals especially in Mubi South Local Government Area (LGA). This has led to a very serious questions on the minds of the citizenry in particular and the professionals in our medical field in general. Ordinary, since typhoid fever is generally associated with a lot of symptoms such as fever, headache, cough etc. these however make it a complicated disease with a very serious economic and social effect on the victims. Therefore, this study seeks to find the prevalent rate of typhoid fever and to suggest possible solutions or ways of preventing it.

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This study is designed to cover Mubi South Local Government Area, Adamawa state Nigeria. Mubi is a town in Northern Senatorial District of Adamawa State, Northeast of Nigeria. It also covered a period of ten years (2011-2020).

Method

Time Series Model

The term model simply means a formalized expression of the situation, which regards as having brought the observed data into being. The relationship between the components of a time series is usually described by the use of time series models and analyst use. There are basically three common models namely; multiplicative, additive and mixed models. However, the additive model is going to be used in this study.

The additive model; this assumes that the components of a time series are independent of one another. An important feature of this model is that the units of T, S, C and I are the same as the units of the actual value Y, the assumption of the independence of the various components in this model is reasonable to an extent, provided we are dealing with a time series of a shallow trend Line or curve over a limited period of time.

Generally, the additive model is given as;

$$Y = T + S + C + I \quad (1)$$

Where:

Y= Observed value of the variable of interest.
T= the trend component
S= seasonal component
C= the cyclical component
I = Irregular or the residual component.

Buys-Ballot Procedure

Christophorus Henrich Diedericus Buys Ballot (October 10, 1817, Kloetinge; Utrecht) was a Dutch chemist and meteorologist after whom Buys-Ballot`s law of atmospheric pressure and Buys Ballot table are named. Buys Ballot devised his tabular method for investigating periodicity in time series data (Fomby, 2008).

Chatfield (2016), reveals the nature of the trend which can describe the pattern in the series. Among other features, the time plot of the periodic means follows the same pattern as the plot of the entire series with respect to the trend. Therefore, instead of looking at the plot of the entire series one may look at only the plot of the period/annual means in order to choose the appropriate trend. Ajaraogu et al. (2017), discovered that the time plot of the entire series is used to make the appropriate choice between the additive, multiplicative and pseudo-additive models. However, in this study we are going to presents Buys Ballot approach in time series analysis for typhoid fever.

Sources of Data.

The data used in this study is purely secondary data, collected from the Medical Record Department/Unit of general hospital Mubi South LGA. Adamawa State Nigeria, from the monthly number of patients treated for typhoid fever.

Method of Data Analysis.

The statistical tool used in this work is the time series analysis using the Buys-Ballot procedure to assess the trend, and hypothesis test about β was used to test if there is significant increase or decrease in the number of cases from 2011-2020.

Simple linear regression was also used to test if there is significant correlation on the rate of people that were affected by typhoid fever from 2011-2020.

The trend line of Buys-Ballot is given by;

$$M_t = a + bt, \quad (2)$$

Where:

$$b^{(c)} = \frac{1}{m-1}\sum b_i^{(c)}$$

Where:

$$b_i = \frac{\Delta \overline{X}}{4}$$

M = is the number of periods in years

$\overline{X}$m = is the last means

$\overline{X}_1$ = is the first mean

n = is the total value of row X column

S = is the number of quarter called season

$$a = \overline{X} - \frac{b^{(c)}}{2}[n+1]$$

The trend line will be obtained from the Buys-Ballot table.

Buys-Ballot Table.

A Buys-Ballot table summarizes data to highlight seasonal variations. Normally, each line is one period (usually a year) and each column is a season of the period/year (4 quarters, 12 months, etc), A cell, (i, j) , of this table contains the mean value for all observations made during the period i at the season j. To analyse the data, it is helpful to include the period and seasonal totals ($T_{i.}$ and $T._j$) , period and seasonal averages ($\overline{X}_{i.}$ and $\overline{X}_{.j}$) , period and seasonal standard deviations ($\hat{\sigma}_{\text{i.}}$ and $\hat{\sigma}_{\text{j}}$) , as part of the Buys-Ballot table. Also included for purposes of analysis are the grand total (T…), grand mean ($\overline{X}...$) and pooled standard deviation($\hat{\sigma}...$). The details of the Buys Ballot Table, see Fomby, 2008.

For easy understanding of the Buys Ballot Table, we defined the row and column totals, averages and standard deviations as follows test statistics;

Test Statistics

$$t = (b - \beta_0)\frac{Sx}{S}[n-1] \tag{3}$$

But $Sx^2 = \frac{\sum x^2}{n} - \left(\frac{\sum x}{n}\right)^2$

$$Sy^2 = \frac{\sum y^2}{n} - \left(\frac{\sum y}{n}\right)^2$$

$$S_i^{\,2} = \frac{n-1}{n-2}\left(Sy^2 - b^2 Sx^2\right)$$

Result and Discussion

Analysis of Data

This chapter deals with the complete decomposition of time series component using Buys-Ballot method, estimation of trend of typhoid fever disease from 2011-2020 and prediction for the future occurrence of the disease for 2021 and 2022. We ascertain the linearity of the data by checking for the Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD) and Mean Squared Deviation (MSD) of the data in linear, quadratic and exponential forms respectively.

Table 1. Test for Linearity of Data using Statistical Product and Service Solution (SPSS) Software.

	Linear	Quadratic	Exponential
MAPE	68.262	68.222	58.516
MAD	4.295	4.292	4.344
MSE	30.371	30.366	32.704

Table 1, shows that the mean absolute percentage error of the linear and quadratic; the line and parabola seems to have the same series point, while the exponential due to its curve had positive

trend. Therefore, the mean absolute percentage (MAPE), is one of the most popular measure of the forecast accuracy, which compare series on different scales and it has shown that there is positive increase in typhoid fever in the area. However, the mean absolute deviation (MAD), it helps us get a sense of how "spread out" the values in a dataset are. In this case, the linear and quadratic has shown that the fever seems to be concentrated in the area under review, the exponential due to it curvature has upsurge it results to 4.344 higher compare to the two. Moreover, the mean squared error (MSE), only tells us how close a fitted line is to data points. Therefore, the linear and quadratic have similar outcome, while the exponential has higher outcome. Hence, the three statistical estimation shows appreciable increase yearly in typhoid fever disease.

Analysis of the Study

To estimate the trend of typhoid fever in Mubi South L.G.A, Adamawa State Nigeria from 2011-2020. This would be achieved using Buys-Ballot procedure, which is;

$$\mathrm{M}_{\mathrm{t}} = a + bt$$

Where:

$$b^{(c)} = \frac{1}{m-1}\sum b_i^{(c)}$$

$$a^{(c)} = \bar{X} - \frac{b^{(c)}}{2}[n+1]$$

And b is the regression slope for Buys Ballot procedure, 'a' is a constant called the intercept.
From the above table, we have

$$\hat{b}^{(c)} = \frac{1}{m-1}\sum b_i^{(c)}$$

$$\hat{b}^{(c)} = \frac{1}{m-1}\sum b_i^{(c)}$$

$$= \frac{1}{10-1}[-0.02]$$

$$= \frac{-0.02}{9}$$

$$a^{(c)} = \bar{X} - \frac{\bar{b}^{(c)}}{2}\left[n+1\right]$$

$$= 3.36 - \frac{(-0.002)}{2}(41)$$

$$= 3.36 + 0.041$$

$$a^{(c)} = 3.401$$

Hence the buys ballot trend line is

$$M_t = a + bt$$

$$M_t = 3.401 - 0.002t$$

To Predict the Rate of Prevalence of Typhoid Fever in the future;
Calculating the Buys –Ballot trend for future occurrence of typhoid fever in Mubi South Local Government Area, Adamawa State Nigeria for the year 2021 and 2022.
Using the equation

$$Y_t = 3.401 - 0.002t$$

For the year 2021:

$Y_t =$ 3.401-0.002(41) = 3.319
3.401-0.002(42) = 3.317
3.401-0.002(43) = 3.315
3.401-0.002(44) = 3.305

For the year 2022:

Y_t = 3.401-0.002(45) = 3.311
3.401-0.002(46) = 3.309
3.401-0.002(47) = 3.307
3.401-0.002(48) = 3.305

The forecast for future occurrence of typhoid fever for the year 2021 and 2022, can be achieved by getting the irregular components and testing for randomness at 95% confidence interval.
This 95% confidence interval (C.I) is gotten by

$$\frac{\pm 2}{\sqrt{n}} = \frac{\pm 2}{\sqrt{40}} = \frac{\pm 2}{6.3246}$$

$$C.I = \pm 0.3162$$

NOTE: In using the test for randomness at 95% confidence interval, it is stipulated that we can accept when we have 1/20 non conformity to the C.I, that is to say that for a sample of 20, we can accept when I is out of this confidence interval and use it to forecast.
From the analysis above it was discovered that 1/20 of the 40 sample does not lie between the C.I which means that we cannot use it to forecast.

The test statistics

$$t = (b - \beta_0)\frac{Sx}{S}[n-1]$$

But $$Sx^2 = \frac{\sum x^2}{n} - \left(\frac{\sum x}{n}\right)^2$$

$$Sy^2 = \frac{\sum y^2}{n} - \left(\frac{\sum y}{n}\right)^2$$

From the transformed table we have

b	=	-0.002
$\sum X^2$	=	22140
$\sum X$	=	820
$\sum Y^2$	=	459.3591
$\sum Y$	=	2883.67
n	=	40

Since b = - 0.002

$$SX^2 = \frac{22140}{40} - \left(\frac{820}{40}\right)^2$$

= 553.5 - 420-25

SX^2 = 133.25

$$SY^2 = \frac{459.3591}{40} - \left(\frac{134.19}{40}\right)^2$$

= 11.4840 - 11.2543

SY^2 = 0.2297

$$S^2 = \frac{40-1}{40-2}\left[0.2297 - (-0.002)^2(133.25)\right]$$

$$S^2 = \frac{39}{38}\left[0.2297 - 0.00004(133.25)\right]$$

$$= 1.0263(0.2297 - 0.0005)$$

$$= 1.0263(0.2292)$$

$$S^2 = 0.2352$$

$$t = (b - \beta_0)\frac{Sx}{S}[n-1]$$

Since $SX^2 = 133.25$

$$Sx = \sqrt{Sx^2} = \sqrt{133.25} = 11.5434$$

$$S = \sqrt{S^2} = \sqrt{0.2352} = 0.4850$$

$$\beta_0 = 0$$

$$t = (-0.002 - 0)\frac{11.5434}{0.4850}[40-1]$$

$$t = (-0.002)(23.80008)(39)$$

$$t = -1.8565$$

(c) Level of significant i.e α =0.05, V = $t_{0.025}$, t = 2.262

Decision Rule

We shall reject H_0 if $t_{cal} > t_{tab}$ at 5% level of significant, otherwise, we accept Ho.

Conclusion, since $t_{cal} < t_{tab}$ which is -1.8565 < 2.262 we shall accept H_0 and hence conclude that there is significant increase in the recorded cases of typhoid fever.

Based on the findings, we discovered that the rate of typhoid fever has been on increase in recent times in Mubi south LGA. And this has created a great challenge to our professionals in medical sector in particular and the society at large, considering the revelation from World Health Organization (WHO, 2018) that about 11-12 million people get sick from typhoid and between 128,000 and 161,000 people die from it every year. However, the modes of transmission of typhoid fever which has been revealed to include through eating or drinking contaminated food or water and through contact with the actually infected person.

The statistical techniques employed in the analysis of data in this project work is time series analysis to determine if there is increase in trend and seasonal variations in the reported incident of typhoid fever from (2011-2020). Therefore, the summary from this study revealed the followings:

- The total number of reported cases of typhoid fever from 2011-2020 was 1,264.
- The estimated seasonal indices show that there was 1.22 in the third quarter of the period under review, which is July, August and September which could be attributed to the raining season because salmonella typhi, the bacteria responsible for the disease is usually gotten from infected foods and vegetables generally in our environment because water flood the whole place after rainfall thereby causing much contamination.
- Furthermore, the predicted quarterly cases of typhoid fever for 2021 and 2022 health year, shows that rate of the incidence is 264 in 2021 and 232 in 2022 health year.
- Finally, this study revealed that typhoid fever can be prevented and controlled though the improvement of sanitary measures, since the bacteria responsible for this illness only survive on human host and are spread by contaminated food and water, and infected persons should go to hospital for adequate treatment not involving in self – medication.

Conclusion

In view of the findings of this study, which seeks to investigate whether there is an increase in trend and seasonal variation in the reported cases of typhoid fever in Mubi South, the following conclusions were drawn from the findings, which include; (1) Between the periods of 2011-2020, the trend has been on increase; (2) There is seasonal variation in the third quarter of the year under study which is July, August and September, usually associated with raining season.

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