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THE IMPACT OF COVID-19 PANDEMIC ON THE TIME SERIES OF MATERNAL MORTALITY IN MT DARWIN DISTRICT, ZIMBABWE.

BY

EDWARD PAUNGANWA

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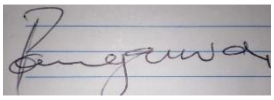

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DEDICATION

I dedicate this project to my parents, sisters, young brother and siblings for the several sacrifices they made helping me to supplementary my education to this tertiary level.

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The Bindura University of Science Education deserves my deepest gratitude for allowing me to be a part of this remarkable leaders' network. I also want to express my gratitude to Mrs. Hlupho, my dissertation supervisor, for her intelligent feedback and recommendations. I also appreciate the careful advice I received from the department of mathematics and physics, and every staff person there. I must conclude by expressing my thankfulness to my family, friends, and colleagues for their unwavering support throughout this extremely demanding academic year. Above all I would like to give thanks to the Almighty God who has superintended me and directed all my efforts throughout this research study.

ABSTRACT

The research examines the influence of the Covid-19 pandemic on the time series of maternal mortality ratio in Zimbabwe concentrating on rural communities in Mt Darwin District. This aim to model the linkage between maternal mortality ratio and the prevalence of covid-19 in Mt Darwin District and also to identify the best predictive model for the maternal mortality. The research, statistically analyze and find the best predictive model. R-studio was used to analyze data to come up with best fit time series model to forecast maternal mortality, and covid-19. The main dependent variable is maternal mortality, dichotomous in nature, and the incidence of covid-19. The research shows that covid-19 has indirect effects on maternal mortality. The research used secondary data to answer the research topic with 72 observations. It also recommended that, the government must also come up with maternal mortality policies to support training and deployments of skilled workers in remote areas, and it should help Mt Darwin District Hospital with services such as ambulances to help in transportation of emergence cases. The government also recommended that; they are needs to assist the community by providing awareness on reducing the number of covid-19 cases.

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List of Acronyms

ACF	Auto-Correlations Function
ADF	Augmented Dickey-Fuller
AR	Auto-Regressive model
COVID-19	Corona Virus Disease 2019
EWMA	Exponentially Weighted Moving Average
MNPI	Maternal and Neonatal Program Index
MM	Maternal Mortality
MMR	Maternal Mortality Ratio
MoHC	Ministry of Health and Child Care
NGO	Non-Governmental Organization
UNFPA	United Nations Population Fund
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Introduction

Maternal mortality is a general health problem worldwide mostly in less economically developed countries. The research examined the influence of the Covid-19 pandemic on the time series of maternal mortality ratio in Zimbabwe concentrating on rural communities in Mt Darwin District. The background of the review will be discussed in this chapter and it will also include, a statement of the problem, objectives of the study, research questions, outlines of the purpose and significance of the study, definition of key terms, and a summary.

1.2 Background of the study

Maternal mortality reduction has long been a top priority for global health and a major concern, particularly in poorer nations. No matter the length or location of the pregnancy, maternal death is defined by the World Health Organization (1993) as the death of a woman while she is pregnant or within 42 days of the termination of her pregnancy from any cause connected to the pregnancy or its management, but not from accidental causes. Despite the ongoing high level of governmental and organizational efforts, maternal mortality continues to be the greatest concern facing less economically developed countries. The Maternal and Neonatal Program Index (MNPI) report (2014) states that Zimbabwe has an unacceptable high rate of maternal mortality, with estimates of 1 300–2 800 women and girls dying from issues related to pregnancy, and roughly 26 000 deaths overall.

Covid-19 was announced as a pandemic by WHO on 11 March 2020, during its 51st situation report. The pandemic caused harmful consequences in almost every country, and the outbreak of the covid-19 pandemic has threatened to become one of the most challenging diseases faced by humanity in modern history, with governments facing diverse health and social and economic challenges. The effects can range from, overpowering healthcare systems, affecting livelihoods, mortality rate, and increasing morbidity.

The incidence of covid-19 in pregnant women is higher than in Ebola, influenza, SARS, and also MERS. It is discovered that pregnant women cannot avoid compulsory examination, therefore, they cannot avoid engagement with healthcare experts. This causes more exposure to the transmission of infection in pregnant women than in non-pregnant women. The facts concerning the effects of pregnancy as well as its co-morbidity on covid-19 related maternal mortality are still undecided (Gaetano Riemma).

The number of women who died during pregnancy or briefly after birth increased significantly during the commencement of the covid-19 pandemic, according to the data from the National Center for Health Statistics, and women continued to experience a maternal mortality rate of more than two times the national average. With the source of what is researched from the pandemic period, pregnant women are at high risk for intense illness from covid-19 as compared to non-pregnant women. Furthermore, pregnant women with covid-19 are at high risk for premature birth and might have an increased risk of other unfavorable pregnancy outcomes (CDC). The influence of the covid-19 pandemic is likely to be a circumstance particular and differ according to differences in country factors.

Covid-19 pandemic increased the mortality rate in the world, and indirectly it is likely to increase maternal mortality as well. The direct and indirect consequences of contracting covid-19 to pregnant women and taking into account the prevention measure have interrupted daily life. The direct effects of covid-19 on pregnancy and postpartum have not yet been shown, in addition to the decrease in obstetric care. It is a compelling question, according to the Harvard T.H. Chan School of Public Health, if pregnant women are more prone to contract the covid-19 infection as well as experience more severe illness outcomes. Besides the direct infection, the pandemic control policies on healthcare facilities, the impact of the pandemic and societies and the world economy may also affect maternal health. There is a need to monitor the health of women during and after pregnancy by improving maternity services in the world, Guzha, (2018).

1.3. Statement of the problem

The covid-19 pandemic has and still expected to have a material impact on global activities and Zimbabwe has been equally affected in almost every sector. Considering the relationship between pandemics and the healthcare system in the past, the healthcare system has never been affected as it is by the covid-19 incidence. The covid-19 pandemic and the consequent lockdown phases have already caused severe damage to various industries. This results to high maternal mortality rate in Mt Darwin District as compared to the past years before the occurrence of covid-19 pandemic. A closer look at the maternal mortality and the impact of covid-19 may assist in reducing the mortality rate and improving maternal healthcare.

1.4.Objectives of the study

This study aims to:

1. To model the linkage between maternal mortality ratio and the prevalence of covid-19 in Mt Darwin District.
2. To identify the best predictive model for the maternal mortality.

1.5.Research questions

The study seeks to answer the following questions:

1. What is the linkage between the maternal mortality ratio and0the prevalence of covid-19 in Mt Darwin District.?
2. What is the best time series model for the maternal mortality in Mt Darwin District?

1.6.Assumptions

1. We assume that there is linearity, that is, the linkage between maternal mortality ratio and the prevalence of covid-19 is linear.
2. The study also assumes that all data was accurately recorded.

1.7.Significance of the study

The health of women is a very important part of the healthcare system in almost every country, so the action of maternal health remains an international priority because of the large number of maternal mortalities from avoidable causes. This thesis will help in monitoring the advancement of strategies to obtain safe health policies by decreasing maternal mortality. The importance of the study is to show how effective the models are in maternal mortality, thus playing a pivotal role in assuring that, the proper mathematical model chosen is supposed to be a useful tool used by the Ministry of health for planning and control of the pandemic to reduce maternal mortality.

1.8.Delimitations of the study

This study was conducted in Mt Darwin District, with a specific emphasis of the incidence of covid-19 on maternal mortality. It is important to highlight that the researcher covered the time period from 2019 to 2021. A sample population of Mt Darwin District hospital was researched in this study.

1.9.Limitations of the study

Time and resources have always remained a constraint, the researcher could not manage to go and have an insight into all places in Mt Darwin. This was a district-based study which means there could be missing information from the data provided as some people fail to report to the clinics and the hospital though not significant. It could also be noted that because of some beliefs such as religion, some mothers fail to report to the hospital for assisted deliveries thus creating room for a slightly biased result. Some information cannot be accessed due to sensitivity and confidentiality, and the researcher will not be able to get some of that information. Nevertheless, the researcher will secure that the information provided will be used for academic purposes only. More so, the research was done concurrently with part four (4) modules, making it a bit challenging for the researcher to share the time equally between the two.

1.10. Definition of terms

Covid-19- Coronavirus Disease 2019, (WHO).

Maternal health - is the health of women during pregnancy, childbirth, and postpartum duration provided by the health care Valentin, D. (2016).

Maternal mortality/ Maternal death – the passing of a woman during her pregnancy or within three months of the termination of her pregnancy, regardless of the duration or location of the pregnancy (WHO).

The maternal mortality ratio – Maternal mortality ratio, is calculated by multiplying the number of maternal fatalities per live birth by a speed and convenience of 100000, (WHO).

Mortality - is the state or condition of being experienced to death or relative period of death in a particular population Filippi, (2006).

Time Series - It is a sequence of numbers collected at regular intervals over some time Kulahci, M. (2015).

1.11. Summary of the study

This introductory chapter clearly emphasizes the subject matter in this thesis, as well as points out the prime focus of this study. The background, statement of the problem, its significance, and limitations were summarized in this chapter. This part of the research shows the background, which motivated the researcher to engage in this research. The statement of the problem defines the challenges to be tackled and this is followed by research objectives that will provide solutions to the challenges when they are realized. This chapter also points out that the research will be an advantage to the Ministry of Health, the government, and policymakers.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

The ambition of the chapter is to roll out the literature closely associated with the incidence of covid-19 on the maternal mortality ratio. This chapter helps to identify a way to achieve the objectives of this study and provides help in choosing the appropriate methodology to use. It also highlights findings from past studies on the incidence of covid-19 on maternal health in other articles and journals. There are two main subsections to be considered, the theoretical literature and the empirical literature. The depth of knowledge and understanding of the topic is in this chapter.

2.2. Theoretical literature review

2.2.1. Time series analysis

Time series is defined as a set of observations x_t, each one being captured at a specific time t (Peter J. and Richard A. Davis-2nd ed). Time series may be denoted by x_1, x_2, x_3……..x_t where t refers to the time and X refers to the values of variable (NCSS, 2013).(Robert H. Shumway.) defined time series analysis as a systematic approach by answering the statistical and mathematical questions determined by these time correlations. Time series analysis involves developing models to gain the meaning of the data to understand the fundamental causes. The number of live births or deaths and the monthly average temperature are examples of time series (Scott L. Zeger, 2005). Time series occur in many fields like economic indicators, business and social sciences follow population series, such as birth rates, mortality rate or school enrollments (Ansah, 2014).

2.2.2. Overview of Time Series

The main goal is to identify a model that captures the time series' pattern. Models are helpful because they explain how two time series can interact, forecast how the series will change in the future, and identify the key characteristics of the time series pattern. The patterns are made up of various elements that together produce the collection of observations in a time series. These elements include trend (T_t), seasonal (S_t), cyclical (C_t), and irregular (I_t). The principle of time series analysis aims to understand the underlying circumstance of the relevant data points through the derivation forecast of future values from recorded past values.

2.2.3. Differencing

Differencing in time series is defined as the transformation of a non-stationary time series into a stationary one by considering its change (Ruey, 2010). Differencing of points is considered an easier way to make a non-stationary mean stationary. A parameter d is the number of time points are differenced to make the process stationary.

Differencing at lag d

We assume that the TS model is additive and there exist both trend and seasonal components, that is

$Y_t = M_t + S_t + X_t,$

the lag-d differencing operator is defined by:

$\nabla dY_t = Y_t - Y_t - d = (1 - \beta d)Y_t.$

By applying the lag-d operator to the model we obtain:

$\nabla dY_t = (mt + st + X_t) - (mt - d + st - d + X_t - d)$

$= v_t - v_{t-d} + X_t - X_{t-d}$.

This eliminates the seasonal effect.

2.2.4. Stationarity and non-stationarity of time series

Stationary time series models assume that the process remains in statistical equilibrium with probabilistic properties that do not change over time, in particular varying about a fixed constant mean level and with constant variance (George, Gwilym, & Gregory, 2008). “A time series $\{w_t\}$ is said to be strictly stationary if the joint distribution of $(w_1,...,w_{tk})$ is identical to that of $(w_{t1+t},...w_{tk+t})$ for all, where k is an arbitrary positive integer and $(t_1,...,t_{tk})$ is a collection of *k* positive integers. A time series $\{w_t\}$ is weakly stationary if both the mean of w_t and covariance between w_t and w_{t-l} are time invariant, where *l* is an arbitrary integer. However, if the time series is normally distributed then weak stationary is equivalent to strict stationary” (Ruey S. , 2010). Any time series with no constant mean over time is nonstationary (J.D.Cryer & Chan, 2008).

2.3. Polynomial Regression and Time Series Smoothing

When there is a curvilinear relationship between the study and the explanatory factors, polynomial models can be applied. Polynomials can occasionally be used to model a nonlinear relationship with a constrained range of explanatory variables. (Abraham and Ledolter, 1986) stated that most autoregressive integrated moving average (ARIMA) models can be expressed in this structural form. The smoothed value of a time series at time t is the conditional expectation of the unknown level at time t, given all available observations (present, past, and future). Polynomial regression is needed when there is no linear correlation fitting all the variable.

The n^{th} order polynomial model in one variable is given by:

$$y = b_0 + b_1 x_1 + b_2 x_1^2 + \dots\dots\dots + b_n x_1^n + \varepsilon$$

If $x_j = x^j, j = 1, 2, ..., ,n$ then the model is multiple linear regressions model in *n* explanatory variables $x_1, x_2, \dots ,n$. So, the linear regression model $y = x\beta + \varepsilon$ includes the polynomial regression model. Thus, the techniques for fitting linear regression model can be used for fitting the polynomial regression model.

2.4. Holt- Winters exponential algorithm

The Holt Winters approach makes advantage of exponential smoothing to encode a significant amount of historical data and utilize it to forecast values for the future. Exponential smoothing is the process of "smoothing" a time series using an exponentially weighted moving average (EWMA). Exponential smoothing is used by Holt Winters' approach to encode a large amount of historical data and utilize it to forecast values for the future. Exponential smoothing model was updated to accommodate for a linear trend, this is known as Holt's exponential smoothing. The smoothed value x_t and its slop are represented by two EWMAs in this model.

$s_t = e x_t + (1-e)(s_t-1+ b_t-1)$

$b_t = \beta(s_t-s_t-1) + (1-\beta)\, b_t-1$

The three components of a time series—average, trend, and seasonality—can be modeled using the Holt winters method. The forecasting model’s equation

$F_{(i+k)} = (L_i + k * B_i) * S_{(i+k-m)}$

2.5. Join points Regression

Joint point regression, as defined by (Martinez-Beneito), is a statistical modeling method that explains the link between two variables by using a segmented linear regression constrained to be prolonged everywhere, in particular, those areas in which the slope of the regression function changes. When modeling time trends in mortality or incidence series for epidemiological studies, this technique is frequently used.

An encompassing model is in introduced when we need to know number of joinpoints need among { N_0, N_1, ……..N_{J*}} in which these model are nested. The main ideas that we present hold for other types of data, not necessarily counting data.

Let x_i be the number of cases of disease during a period of time, represented by t_i . suppose that:

$x_i \sim Poisson\ (\mu i)\ i = 1, ..., n$

defined as:

$$log(\mu_i) = log(P_i) + \alpha + \beta_0 \cdot (t_i - \bar{t}) + \sum_{j=1}^{J^*} \delta_j \cdot (\beta_j \cdot \mathcal{B}_{\tau_j}(t_i))$$

where *Pi* is the population under study during year *i*.

2.6. Empirical literature review

Carvalho Sauer et al. (2021), aimed to verify the relationship between the maternal mortality ratio and the incidence of covid-19. Their thesis has a time series of maternal mortality ratio, which was analyzed using polynomial regression and were predicted by the additive Holt- Winters exponential smoothing algorithm and the accuracy of the forecasts was by checking the smoothing coefficient and the mean errors. This conclude that the covid-19 pandemic may be directly and indirectly related to this increase, which needs to be investigated. An urgent public action is needed to prevent and reduce maternal deaths during this pandemic.

The time series of causes of maternal mortality in relation to the influenza virus pandemic. A natural experiment with a large sample size, using Argentina's national vital statistics from 1980 to 2017 was published by Elard S. Koch, (2021) and was titled "Impact of emerging viral pandemic on cause-specific maternal mortality time series." The maternal mortality ratio time series was modeled using join points regression models. Using a panel of experts, it was possible to assess the registry's sensitivity to spot the impact of the pandemic H1N1 2009 influenza virus on cause-specific MMR (ITS). Regression analysis found an average decrease, and concurrent ITS studies showed that the pandemic H1N1 virus increased mortality from complications involving the respiratory system and sepsis before having a reversible effect following the outbreak. It had no impact.

The rigorous lockdown that limited people's movements caused by the covid-19 pandemic had an impact on maternal, neonatal, and child health outcomes globally and restricted access to services. Burt JF, Ouma J, and Lubyayi, (2021) conducted an observational study in the Kawempe region of Kampala utilizing regularly gathered data from electronic medical records. The effect on services for sexual and reproductive health from July 2019 to December 2020 was evaluated using an interrupted time series analysis. Prior to (July 2019–March 2020), during (April 2020–June 2020), and during the nationwide lockdown, descriptive statistics detailed the key outcomes (July 2020–December 2020).

Health services were disrupted in Zimbabwe as a result of the COVID-19 pandemic lockdown. A comparative maternal audit titled "Impact of covid-19 on Maternal and Perinatal Outcomes in Harare, Zimbabwe" was published in Bikwa (2021). The study found that the nationwide lockdown raised the probability of adverse maternal and newborn outcomes while decreasing the use of maternal health services. To lessen the pandemic's harmful side effects, mother and newborn health services must still be made available in the midst of the outbreak. The relationship between the year and maternal/perinatal outcomes was evaluated using univariate logistic regression models. Version 16 of STATA was used for all statistical analyses.

2.7. Chapter summary

The chapter examined a previous thesis on the consequences of the covid-19 and other pandemics on maternal mortality. The impact of the covid-19 outbreak on time series of maternal mortality ratio in the Mt Darwin District was explored and analyzed using the data from this chapter as a starting point. In order to better determine which model best explains the association between maternal mortality and the occurrence of covid-19, this investigation is therefore unavoidable. The methods used to acquire and analyze the study's data as well as its methodology will be covered in the following chapter.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

Research methodology is a methodical, scientific approach to issue resolutions and how the research is to be undertaken, according to (Kothari. M 2003). The objective of this part is to focus on the technique employed in this investigation. The study methodology, data sources, data collection strategies, and research tools are the main topics of this chapter. It also explores how the algorithm that will be utilized for predictions is being developed.

3.2. Research Design

According to (Kumar, 2011), a research design is an arrangement of parameters for data collecting and analysis that seeks to balance procedural economy with relevance to the study goal. Since it offers responses to the research questions, it serves as the study's primary tool. To assess how much of an influence covid-19 makes in maternal mortality, the researcher used a quantitative research design. According to Burn and Grove (1993), quantitative research is a formal, objective, systematic procedure that uses numerical data to learn about the universe and uses mathematical manipulation to predict what will happen in the future.

3.3. Research Instrument

According to Saunders (2009), research instruments are tools that are used to collect data in a methodical manner. The data gathered for the study were analyzed using Microsoft Excel and the statistical software tool R-Studio. To access earlier work that provides a comprehensive collection and the information utilized in literature reviews, as well as to access papers, journals, and theories to conduct the research, the internet and textbooks were employed.

3.4. Data Collection

A structured method of acquiring and evaluating data is called data collection. It facilitates the researcher in collecting the data necessary for study subjects, helps them respond to appropriate questions, and helps them evaluate results. The investigation of secondary data collection techniques is the foundation of this study. The phrase "secondary data" describes the information that previously existed before the research was conducted. The researcher used secondary data from the statistics for the years 2019–2021 from the Mt. Darwin District Hospital.

3.5. Data Presentation and Analysis

Data presentation is the process of arranging and graphically presenting data in different graphical presentations such that logical and statistical inferences can be made from the collected data, Smeeton (2003). Data analysis, according to Rossman (1995), is the process of putting the information acquired during the study gathering phase into some kind of order, structure, or perspective.

3.5.1. Description of variables

Variables	Symbol	Description	Source
Maternal mortality	*MM*	Mortality recorded at the facility	Ministry of Health and child care
Covid-19	*C19*	Covid-19 pandemic lockdown	Ministry of Health and child care

Table 3.1: Descriptive of variables

Maternal mortality

Maternal mortality, according to (Lancet, 2006), is the death of a woman while she is pregnant or within 42 days of her pregnancy's termination, regardless of the length of the pregnancy or the location of the birth, from any cause associated also with pregnancy or its management, but not caused by accidental causes. Every year, over 180 women die from conditions connected to pregnancy, and the majority (99%) of these pregnancy-related deaths have occurred in underdeveloped nations. The maternal mortality ratio was estimated by dividing the total number of maternal deaths during the research period by 100,000 live births.

Justification: Maternal mortality is important to include in Mt Darwin's district healthcare system. This is the main variable in this study, all healthcare is affected by maternal mortality, which is an important measure of maternal health.

Covid-19

The coronavirus, known as covid-19, is an acute respiratory illness that can be fatal in certain cases and has serious symptoms, particularly in the elderly and those with underlying problems. Initially proven from China in 2019, and it spread worldwide in 2020. The pandemic has put the world's best healthcare systems' resilience to the test. As a result, nations are being forced into complete lockdowns since it has become a threat to public health on a worldwide scale. Both the provision and use of maternal and paediatric healthcare services are being significantly impacted by how the public healthcare delivery system is responding to the covid-19 pandemic. The demand for healthcare services will suddenly decline as a result of social distances and restrictions meant to slow and control the spread of disease (e.g., restricting queues and movements). Since the first death was reported in Zimbabwe in March 2020, the number of deaths has risen.

Justification: In this case, Covid-19 is the main variable under analysis hence it is of greater significance to analyze its relationship from all perspectives. Covid-19 pandemic lockdown resulted in commotion of health services in Zimbabwe.

3.5.2. Descriptive statistics

A data set can be analyzed using descriptive statistics, which can be displayed graphically or tabularly. The main goals of this analysis demonstration are to illustrate the variability and assess the normality of the variables. The analysis table provide the total number of observations, mean, median, skewness, kurtosis, and standard deviation.

3.5.3. Correlation

The correlation is a statistical tool that assists in the investigation of the linear relationship (straight line) between the variables under consideration, and the correlation value ranges from -1.00 to +1.00. According to Gogtay (2017), a correlation of +1.0 shows a perfect positive correlation between variables in a linear form, a correlation of -1.00 suggests a perfect negative correlation, and a correlation of 0.0 implies no linear relationship between the variables. In this study, the Pearson's coefficient of correlation (r) was used to evaluate the statistical link between continuous variables.

3.5.4. Unit root tests for stationarity

It is crucial to check the sequence of integration of each variable data series so that no series is integrated at I (2), even though the boundaries test for serial correlation does not call for pre-testing the variables for unit root (Odhiambo, 2008). The Augmented Dickey-Fuller (ADF) test was utilized in this study to check for unit root. The creators of this were Dickey and Fuller (1979). An enhanced Dickey-Fuller test (ADF), used in statistics and econometrics, examines the possibility that a unit root exists in a time series sample. Depending on the test version employed, the alternative hypothesis varies, although it is typically stationarity or trend-stationarity.

3.5.5. Polynomial regression

When the relationship between the study and the explanatory factors is curvilinear, polynomial models can be applied. Polynomials can also be used to model nonlinear relationships in small ranges of explanatory variables. According to Abraham and Ledolter (1986), the majority of autoregressive integrated moving average (ARIMA) models can be described in this structural form. The smoothed value of a time series at time t is the conditional expectation of the unknown level at time t, given all available observations (present, past, and future). When there is no linear association that fits every variable, polynomial regression is essential.

To apply the regression procedure, the researcher selected

Y: The dependent variable of maternal mortality

X: The response variables,

X_1_Covid-19

The n^{th} order polynomial model in one variable is given by:

$$y = b_0 + b_1 x_1 + b_2 x_1^2 + \ldots\ldots\ldots + b_n x_1^n + \varepsilon$$

If $x_j = x^{j,} j = 1, 2, \ldots ,n$ then the model is multiple linear regressions model in n explanatory variables $x_{1,} x_2 , \ldots ,n$. So, the linear regression model $y = x\beta + \varepsilon$ includes the polynomial regression model. Thus, the techniques for fitting0linear regression model can be used for fitting the polynomial regression model.

3.5.6. Holt- Winters exponential algorithm

Exponential smoothing is used by Holt Winters' approach to encode a large amount of historical data and utilize it to forecast values for the future. Holt's technique was expanded upon by Winters and Holt in 1957 in order to account for seasonality. There are two versions of this procedure, and the seasonal component in each one is different. When seasonal fluctuations are essentially constant throughout the series, the additive method is recommended; when they change proportionally to the level of the series, the multiplicative method is favored. Exponential smoothing is the process of "smoothing" a time series using an exponentially weighted moving average (EWMA). A lot of historical data is encoded using the Holt Winters method's exponential smoothing in order to forecast future values.

3.6. Chapter summary

The data collection methods, research plan, research processes, and tools used in the study were all disclosed in the methodology chapter. The research study's methodologies it was further examined in the chapter. Models that could aid in attaining these outcomes and findings were highlighted in order to produce inferential and descriptive statistics. This chapter also covered model accuracy metrics and performance evaluation techniques.

CHAPTER 4: ANALYSIS AND PRESENTATION OF DATA

4.1. Introduction

In this chapter maternal mortality analysis would be conducted using a polynomial regression model and the research presents the data collected in the prior chapter. Data was analyzed using R-studio, software and the findings of the research include the summary of original results for the statistical analysis of the correlation between maternal mortality and covid-19 Mt Darwin District Hospital.

4.2. Summary Statistics

The researcher used monthly data from January 2019 to December 2021. This section represents a summary of the data properties.

Table 4.1: Descriptive statistics

Variables	Maternal Deaths	Covid-19
Mean	0.6944444	44.58333
Std. Dev.	0.7099072	118.8904
Variance	0.5039683	14134.94
Skewness	0.5018281	2.851836
Kurtosis	2.126468	9.692922
Obs	36	36

Source: authors computation

The summary statistics of the explanatory variable, maternal mortality and the independent variable covid-19. Then considering the skewness, the results demonstrate that all the variables are positively skewed and this implies that all these distributions have right tails. The mean and skewness for all variables are both positive which indicates that there are increasing.

4.3. Multicollinearity

Table 4.2: correlation results

	Maternal Deaths	Covid-19
Maternal Deaths	1.00	
Covid-19	0.1768	1.00

Source: authors computation

The strength of coefficient correlation can range from -1.00 to +1.00, the larger the absolute value of the coefficient, the stronger the relationship between the variables. The correlation matrix shows the relationship between variables, a positive sign indicates a positive relationship meaning that a rise in one variable leads to the rise of the other, and a negative sign indicates that one variable increases and the other decreases, and the value of zero for correlation indicates the relationship among tested variables. From table 4.3, it can be shown that all variables are a positive relationship between all variables, this implies that an increase in one variable results in an increase to another variable, and there is a semi-strong relationship between all variables.

Table 4.3: Kendall's correlation coefficients test

	Maternal Deaths	Covid-19
Maternal Deaths	1.00	
Covid-19	0.5003	1.00

Source: authors computation

According to Sureka,2021 defined multicollinearity as a statistical phenomenon in which two or more variables in a regression model are dependent upon the other variable in such a way that one could be linearly predicted from the other variables with a high degree of accuracy. After testing for the presence of multicollinearity, we found that there was no multicollinearity amongst the explanatory variables.

4.4. Stationarity

The Augmented Dicky-Fuller Test

Table 4.4(i) Maternal deaths

	Test statistics	1% Critical value	5% Critical value	10% Critical value
Z(t)	-5.524	-3.750	-3.000	-2.630

Source: authors computation

Table 4.4(ii) Covid-19

	Test statistics	1% Critical value	5% Critical value	10% Critical value
Z(t)	3.697	-2.660	-1.950	-1.600

Source: authors computation

The Augmented Dicky-Fuller Hypothesis

H_0: Data is non-stationary

$H\alpha$: Data is stationary

From the Dicky-Fuller test results, the t-statistics (-5.524) from table 4.4(i) and (3.697) from table 4.4(ii), is greater than the critical value at 95% level of significance. This implies that we reject the null hypothesis of the ADF which state that there is non-stationarity and conclude that our data is stationary.

4.5. Linear Regression

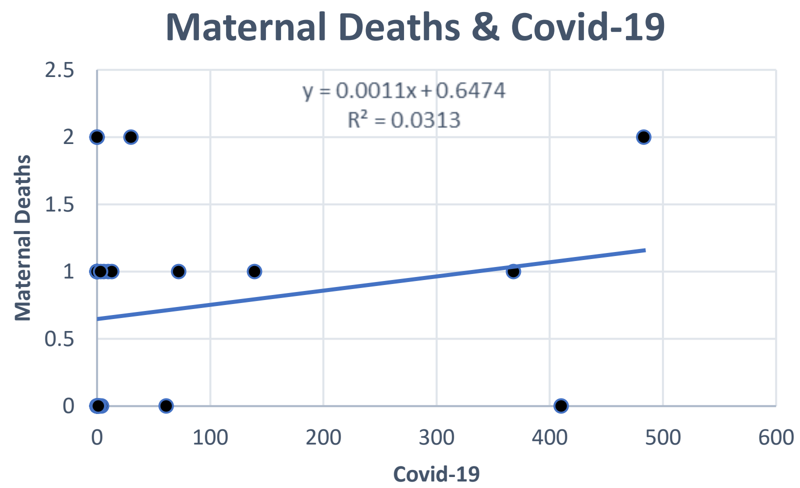

Figure 4.0: linear regression

The World Almanac and Book of facts, (1993), Linear regression attempt to model the linkage between two variables by fitting a linear equation to the data, one variable is measured to be an explanatory (covid-19), and the other is considered to be a dependent variable (maternal deaths). The researcher wants to determine if there is a relationship between maternal deaths and covid-19. The scatterplot above shows the data and the line of best fit with the R^2 of 0.0313 which means the model fit the data with 3.1%, the explained variable variation that is explained by the linear model. This demonstrate there is no linear relationship between covid-19 and maternal deaths and it also indicate a slight prediction interval. This shows that, from the empirical results in chapter 2, there is evidence that covid-19 has both direct and indirect effects on maternal mortality and this is also indicated by the percentage of R^2.

4.6. Polynomial regression model

Im.final = Im('Maternal Deaths'~ poly('Covid-19',10), data = data2, na.action=na.exclude)

Table 4.5: Polynomial regression model

	Estimate	Std. Err	t-value	Pr(>|t|)	
Intercept	0.6944	0.105	6.616	6.24-07	***
C19	1.1	0.6298	1.747	0.093	.
(2)C19	1.4376	0.6298	2.283	0.0312	*
(3)C19	1.4392	0.6298	2.285	0.0311	*

Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

The p value of the independent variable was used to determine if the variable will be kept in final model of regression. Therefore, by using significant *'β'* values, polynomial estimate, the maternal death prediction model could be fitted as:

$MM = 0.6944 + \beta\ C19 + \beta\ (2)C19 + \beta\ (3)C19$

Which implies that:

$Y = 0.6944 + 1.1X_1 + 1.4376(2)X_1 + 1.4392(3)X_1$

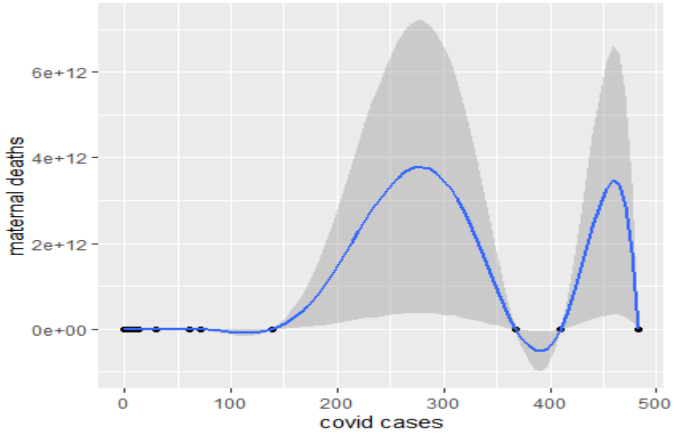

Figure 4.1: Polynomial fitted model

The greater the percentage of variation that the regression model explanation for, the closer it is to a perfect model, (Meyer and Mafini, 2016). R-squared value was 0.2129, indicating that the explanation procedures studied clarified almost 20% of the variance. This indicate that, greater amount of unexplained variation, therefore the R^2 was bound to be lower. A low adjusted R-squared of 0.2129 does not necessarily indicate that the model has a bad fit. The fitted line indicates the relationship between maternal deaths and covid-19. The incidence of covid-19 on maternal deaths was analyzed using polynomial regression of order 10.

Table 4.6: Analysis of variance table

Response: Maternal Deaths	Df	Sum Sq	Mean Sq	F value	Pr(>F)
poly (`Covid-19`, 10)	10	7.7219	0.77219	1.9466	0.08594 .
Residuals	25	9.9170	0.39668		

Signif. codes: 0 ‘*’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1**

According to the empirical results of Carvalho (2021), stated that maternal mortality and temporal relationship with the incidence of covid-19. As the F-statistics of 1.9466 is less than the critical value 2.24, we fail to reject the null hypothesis, and the model is significant at 0.05. This concludes that there is no enough evidence to support the relationship between the maternal deaths (predictor variable) and the covid-19 (response variable).

4.6.1. Model validation testing

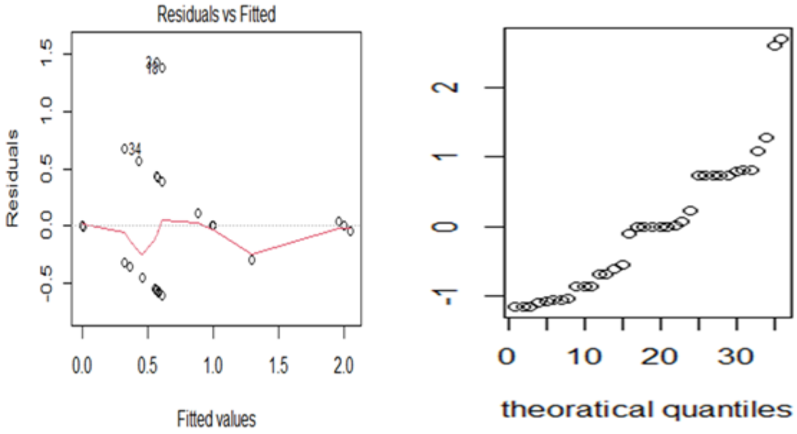

Figure 4.2: validation test

These two diagnostic plots show that the model fits the data. The residual plot shows an increase and decrease trend which suggest that residuals are not identically distributed around 0. The QQ plot shows that the residual values are not extreme value of a normal distribution.

4.7.Forecast

These findings are consistent with the literature of the study as it is shown by the results below:

plot(hw1fo,ylab="maternal deaths", xlim=c(2020,2023))

lines(hw1fo$fitted, lty=2, col="green")

acf(hw1fo$residuals,lag.max = 20, na.action = na.pass)

hist(hw1fo$residuals)

Box.test(hw1fo$residuals, lag = 20, type = "Ljung-Box")

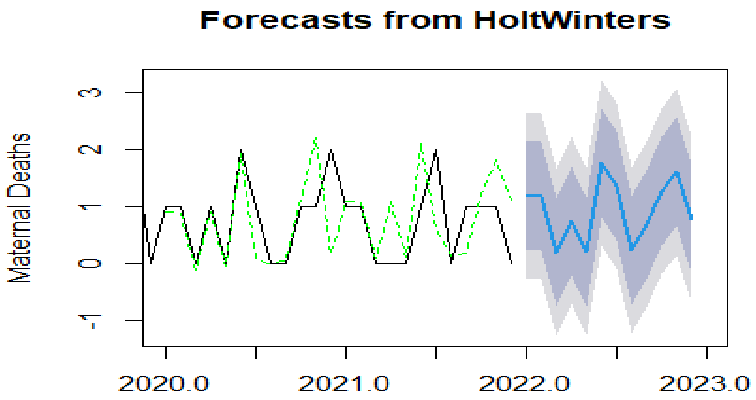

Figure 4.3: Maternal deaths forecast

Hyndman (2021), stated that the Holt-Winters model considered to be strong and has exceptional performance on short-range forecast. The figure 4.3 illustrated the forecast of maternal deaths from January 2022 to December 2022.

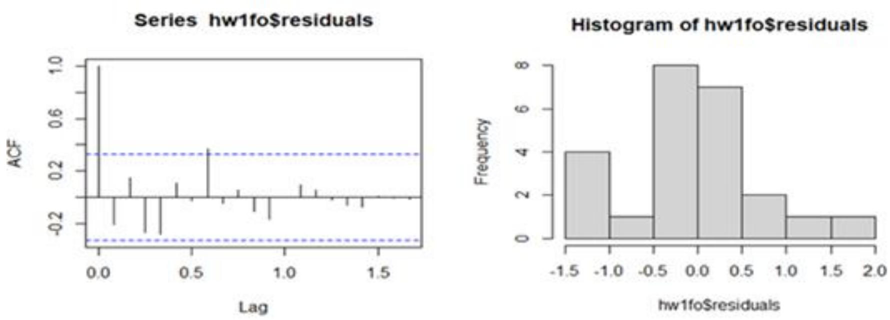

Figure 4.3(i): Maternal forecast evaluation

Box-Ljung test: X-squared = 15.479, df = 20, p-value = 0.7484

Forecast accuracy was measured by evaluating the residuals. The p value for Ljung-Box is above statistical which is 0.75, which means the evaluation has desirable results to the model. the ACF represent the significant threshold level and the histogram also show the model is normal distributed.

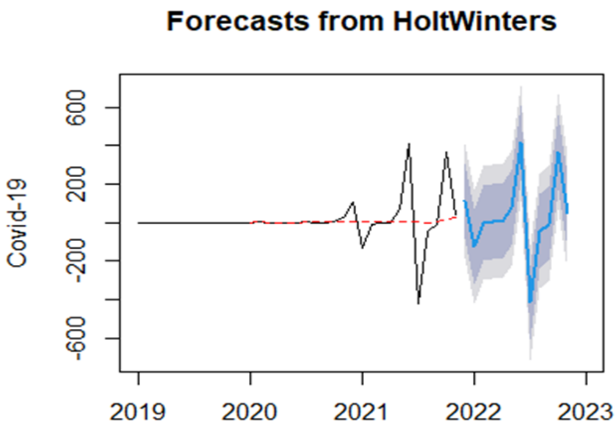

Figure 4.4: covid-19 forecast

The figure 4.4 illustrated the forecast of covid-19 from January 2022 to December 2022

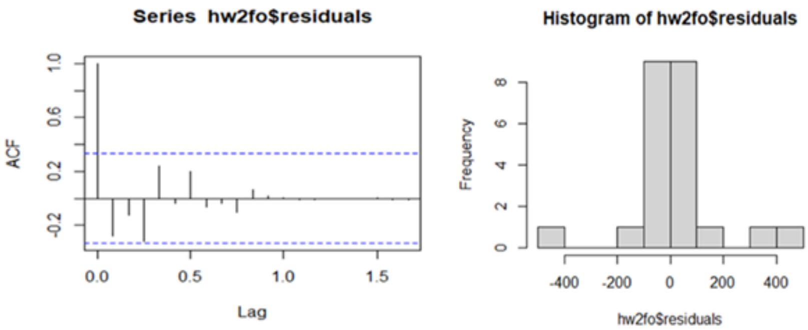

Figure 4.4(i): Covid-19 forecast evaluation

Box-Ljung test: X-squared = 9.446, df = 20, p-value = 0.9771

Forecast accuracy of covid-19 was measured by evaluating the residuals. The p value for Ljung-Box is 0.98, which means the evaluation has perfect results to the model. This is also illustrated by the normal distribution that has been shown by the histogram.

4.8. Chapter Summary

This chapter depicts data analysis as well as data presentation which enabled the researcher to come up with the best fit model. The data was presented in tables, analyses through R studio and STATA was performed to show variability and predict the future values of maternal mortality and covid-19. The models were able to capture and represent the conditional variance in the data based on the model fit tests, indicating the results are accurate and valid. The subsequent chapter five will concentrate on the summary outcomes, recommendation and the conclusion.

CHAPTER 5: SUMMARY, CONCLUSION and RECOMMENDATIONS

5.1. Introduction

The chapter provides an impression of the polynomial regression model of maternal mortality, and covid-19 in Mt Darwin District and the recommendations for predicting holt-winter's method. Before concluding the chapter, the researcher gives some recommendations to particularly the policymakers, health workers and the society operating and exist in the same environment in which the study was conducted.

5.2.Summary of the Findings

The idea of this study was to make an investigation into the analysis of maternal mortality and its prime determinates based on the findings from Mt Darwin District Hospital, Mashonaland Central Province, Zimbabwe. Therefore, the researcher had to find the best fit time series model to forecast for the next 12 months. R-studio, and Stata software was used to run the data. The study has viewed maternal mortality as an outcome variable that is related to a lot of underlying factors that were involved in the research in order to predict if it was directly or indirectly affected by the incidence of covid-19 pandemic.

The study swotted that there is no linkage between the maternal mortality and the prevalence of covid-19 since the model is not significant at 0.05. This indicate that covid-19 is predictor element of maternal mortality, and the probability of death from covid-19 are very slim since the correlation is almost zero (0.176).

The research used both quantitative and qualitative approach methods since it verified to be the most pertinent and appropriate for the research in accomplishing the anticipated objectives. The researcher employs the polynomial regression model and holt-winter's method because of its ability to predict the future results. In this case, the oscillation in maternal mortality qualified to predictable values, was observed throughout the 2022months; however, when the covid-19 epidemic fluctuates. Of the 25 registered maternal deaths in 2019 to 2021 only 3 had Covid-19 declared as the cause of death. Holt-Winter's is a powerful tool for predicting future data in a time series. Values for was predicted by Holt-Winters, based on the 2019 to 2021 monthly maternal deaths time series, smoothing coefficients, alpha=0.2, beta=0.1 and gamma=0.1. The forecast results achieved were significant as the forecasted values ranged between the upper limit and lower limit of the 95% confidence intervals.

5.3. Conclusions

The study revealed the instability in maternal mortality, and its temporal relationship with the incidence of covid-19 in Mt Darwin district in 2022. The covid-19 pandemic may be directly and indirectly related to this increase, which needs to be investigated. The holt-winter's forecasting proved to be useful and reliable in achieving accurate forecasts. The research used monthly data analysis from period 2019/01/01 to 2021/01/01. Therefore, Holt-winter's forecasting is a power full tool for predicting future data in a time series.

5.4. Recommendations

Proceeding the foundation of the results, the research, recommends other scholars to conduct the forecasting process using different models to come up with the best fit model. An imperative public health action is needed to prevent and reduce maternal deaths during this pandemic, in Mt Darwin district. The NGOs can play a fundamental role by contributing in reduction of maternal mortality by initiating programs that will provide education that helps in reduction of maternal mortality. The government needs to assist the community by providing awareness on reducing number of covid-19 cases. The Zimbabwean government should increase funds for trainings and equipment should also increase surgical repair of complications associated with maternal deaths. The government must also come up with maternal mortality policies to support training and deployments of skilled workers in remote areas, and it should help Mt Darwin District Hospital with services such as ambulances to help in transportation of emergence cases.

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Gaetano Riemma, Department of Woman, Child and General and Specialized Surgery, Obstetrics and Gynecology Unit, University of Campania “Luigi Vanvitelli,” Largo Madonna delle Grazie 1, 80138 Napoli, It

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Harvard T.H. Chan School of Public Health, Boston, MA, USA. 2 George Washington University, Washington, DC, USA. 3 Brown University, Providence, Rhode Island, USA. 4 Department of Social and Behavioral Science, Harvard T.H. Chan School of Public Health, 677 Huntington Ave., Boston, MA 02115, USA.

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Appendix

Appendix A: Forecast maternal deaths

maternalfo <- forecast(hw1, h=12, level = c(80,95))

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
Jan 2022	1.2040210	0.2500148	2.158027	-0.25500557	2.663048
Feb 2022	1.1947738	0.2407675	2.148780	-0.26425284	2.653800
Mar 2022	0.1986843	-0.7553219	1.152691	-1.26034230	1.657711
Apr 2022	0.7645444	-0.1894619	1.718551	-0.69448225	2.223571
May 2022	0.2196632	-0.7343430	1.173669	-1.23936343	1.678690
Jun 2022	1.7723654	0.8183592	2.726372	0.31333882	3.231392
Jul 2022	1.3760631	0.4220569	2.330069	-0.08296353	2.835090
Aug 2022	0.2313948	-0.7226114	1.185401	-1.22763182	1.690421
Sep 2022	0.6865136	-0.2674926	1.640520	-0.77251300	2.145540
Oct 2022	1.2786893	0.3246830	2.232695	-0.18033734	2.737716
Nov 2022	1.6115449	0.6575386	2.565551	0.15251826	3.070571
Dec 2022	0.7788349	-0.1751714	1.732841	-0.68019176	2.237861

Appendix B: Forecast covid-19

covidfo <- forecast(hw2, h=12, level = c(80,95))

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
Jan 2022	-125.138112	-320.02032	69.74409	-423.18472	172.9085
Feb 2022	-4.138112	-199.02032	190.74409	-302.18472	293.9085
Mar 2022	2.861888	-192.02032	197.74409	-295.18472	300.9085
Apr 2022	3.861888	-191.02032	198.74409	-294.18472	301.9085
May 2022	74.861888	-120.02032	269.74409	-223.18472	372.9085
Jun 2022	414.861888	219.97968	609.74409	116.81528	712.9085
Jul 2022	-418.138112	-613.02032	-223.25591	-716.18472	-120.0915
Aug 2022	-44.138112	-239.02032	150.74409	-342.18472	253.9085
Sep 2022	-6.138112	-201.02032	188.74409	-304.18472	291.9085
Oct 2022	368.861888	173.97968	563.74409	70.81528	666.9085
Nov 2022	45.861888	-149.02032	240.74409	-252.18472	343.9085
Dec 2021	112.861888	-82.02032	307.74409	-185.18472	410.9085