Asian Journal of Advances in Research

4(1): 1112-1121, 2021

A STUDY ON MORTALITY RATE FOR INFANT IN PAKISTAN: AN APPLICATION OF BIOSTATISTICS

JAMAL ABDUL NASIR[1*], CHRISTOPHE CHESNEAU[2], MUHAMMAD IMRAN[3], AND FARRUKH JAMAL[4]

[1]Department of Statistics, GC University Lahore, Pakistan.
[2]Department of Mathematics, LMNO, University of Caen, Caen 14032, France.
[3]CRS, Lodhran, Pakistan.
[4]Department of Statistics, The Islamia University Bahawalpur, Pakistan.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Received: 06 August 2021
Accepted: 12 October 2021
Published: 14 October 2021

Original Research Article

ABSTRACT

The annual mortality rate (per 1,000 live births) from 1960 to 2017 of Pakistan is the subject of this paper. As a reason, in South Asia, Pakistan contributed the most to childhood mortality, including infant mortality. Despite progress, child mortality has declined globally, but Pakistan is still struggling and far behind the targets of the Sustainable Development Goals. There are several reasons for high childhood mortality, including socioeconomic determinants and lack of effective implementation of health-related policies, particularly in primary health care settings. In the present study, we use stochastic univariate models to uncover the trend of infant mortality by using more than half a century of data from 1960–2017. The secondary data related to the mortality rate (per 1,000 live births) from 1960 to 2017 was extracted from the World Bank Dataset. Descriptive and time series analysis (Box-Jenkins) are applied. The analysis is carried out using the R programming language.

Keywords: Forecast; infant mortality rate in Pakistan; time series model.

1. INTRODUCTION

The world has made significant progress in reducing child mortality, including infant mortality, over the past quarter of a century. Globally, the infant mortality rate (IMR) has dropped from an estimated rate of 65/1,000 deaths per live birthin 1990 to 29/1,000 deaths per live birth in 2017 [1]. Annual infant deaths in 1990 were 8.8 million and reduced to 4.1 million in 2017 [1]. The risk of a child dying before completing the first year of age was highest in the World Health Organization (WHO) African Region (51 per 1000 live births), over six times higher than in the European region (8 per 1000 live births) [1]. According to the 2018 United Nations Inter-agency Group for Child Mortality Estimation report, an estimated 6.3 million children and young adolescents died in 2017 [2]. The report also showed that children under age 5 accounted for 5.4 million deaths (with 2.5 million neonatal and 1.6 million infants), a considerable portion of the total deaths of 6.3 million [2]. Five countries, including India, Pakistan, Nigeria, the Democratic Republic of the Congo, and Ethiopia, accounted for the highest

**Corresponding author: Email: dr.jamal@gcu.edu.pk,;*

number of newborn deaths, 39% of those occurred in Southern Asia and 38% in sub-Saharan Africa [3].

Pakistan is the sixth most populated country in the world, with a lower literacy rate, a higher proportion of people living in rural areas, and limited health care settings and quality of life. Pakistan is among the countries that contribute to 50% of all newborn deaths [3]. In South Asia, Pakistan placed at top with highest IMR (64/1,000 live births) followed by the neighboring border sharing country Afghanistan (53/1,000), India (35/1,000), Bangladesh (28/1,000), Nepal (28/1,000), Iran (13/1,000) and Sri Lanka (8/1,000) [4]. According to the Pakistan Medical As per the Pakistan Medical Association, unsafe delivery practices are considered as one of the causes of high infant and maternal mortality rates in Pakistan. Non-hospital deliveries are not inherently bad, but in rural areas, due to untrained dais and unsanitary practices, maternal and infant mortality rates are higher.

Although the mortality rates have declined among children of all age groups over the last couple of decades, millions of children die every year, mostly of preventable or treatable causes like lower respiratory tract infections, malnutrition, diarrhea, pneumonia, measles, fever, malaria, absence of breastfeeding practices, and artificial feeding in infants.

Socioeconomic constraints are yet another important concern in low and middle-income countries, where infant mortality claims a considerable portion of total deaths each year. Many authors contributed through scientific studies to underline the major socioeconomic factors that have had a substantial effect on higher child mortality, including infants. Khadka, Lieberman [5] used the socio-economic factors of infant mortality in Nepal and yielded that poor and middle classes had higher infant mortality compared to wealthier classes [4]. Liu and Chen [6] used data from the World Bank of 114 countries to underline the association of IMR with economic strength and socioeconomic constraint. Government health expenditure and female education are negatively related to the infant mortality rate, but the fertility rate is positively related to the infant mortality rate. The mother's education, geographical area of residence, place of delivery, low birth weight, both parents working, mothers receiving blood transfusions during their previous pregnancy, fertility rate with short birth interval, delivery assistant type, breastfeeding status, antenatal care, child immunization, and mother age were all linked to infant deaths [5–7–11].

This study aimed to underline the trend and pattern of infant mortality in Pakistan from 1960 to 2017 by using stochastic time series models. As developing nations are facing a high mortality rate globally, effective implementation of statistical tools increases the likelihood of better understanding the pattern of vital events so that timely intervention through adequate planning can be ensured. This is a significant concern for Pakistan.

2. METHODOLOGY

The present study uses secondary time series data from 1960 to 2017 of the infant mortality rate taken from the World Bank Data Infant Mortality Rate (https://data.worldbank.org/indicator/SP.DYN.IMRT.IN). The R programming language is employed in order to complete descriptive and time-series analysis [12].

Conventionally, the mortality pattern is understood through various mortality measures, including death rates, ratios, and life expectancy. Modeling the mortality curve is a less conventional approach, although it has been introduced in the literature quite long ago with the pioneering work of Gompertz, who identified an exponential increase in death rates with age (Gompertz 1825). After that, many other researchers made their contributions to these models under different formulations [13 to 17]. The Box-Jenkins model is used to explore the pattern of IMR per 1,000 live births from 1960 to 2017 [18-19].

The descriptive analysis of annual infant mortality rates (per 1,000 live births) from 1960 to 2017 is illustrated by the box plot in Fig. 1. The median IMR was 109 per 1,000 live births, whereas a higher (188.5) IMR was reported in 1960. The constant gradual decline in infant mortality rates from 1990 to 2017 was the first time since 1990 that the rate remained at 61.2 per 1,000 live births in 2017. The temporal analysis in Fig. 2 from 1960 to 2017 shows a gradual reduction in infant mortality rates every year. Also, it shows that the IMR was over 100 from 1960 to 1993 and remained below 100 from 1994 to present. Figs. 3 and 4 illustrate the auto correlation function (ACF) and partial auto correlation function (PACF), respectively.

2.1 Time Series Analysis

In the present study, we use the R programming language to uncover the trend of infant mortality series from 1960 to 2017. The ARIMA(1, 2, 2) model is found to be an adequate forecasting model using the Auto ARIMA function with a root mean square error of 0.1006. This model indicates that the actual series turned out to be stationary after the second difference order with AR(1) and MA(2). The estimated parameters along with standard error are illustrated in Table 1. A five-year-ahead forecast is obtained and yielded that an average 5.6% decline per year in IMR is expected. The detailed description of the forecast, along with the 80% and 95% confidence intervals (C.I.), are shown in Table 2. Under the ARIMA(1,2,2) model, the time plot of actual and predicted values of IMR shows good agreement between actual and predicted values of IMR in Fig. 5. While Fig 6 shows the plot of forecasts along with 80% and 95% of the lower and upper C.I. The ACF and PACF are presented in Fig. 7 and 8, respectively. A residual analysis is displayed in Fig. 9.

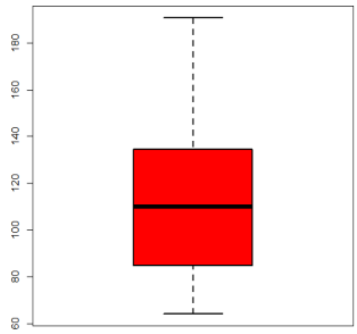

Fig. 1. Box plot of IMR

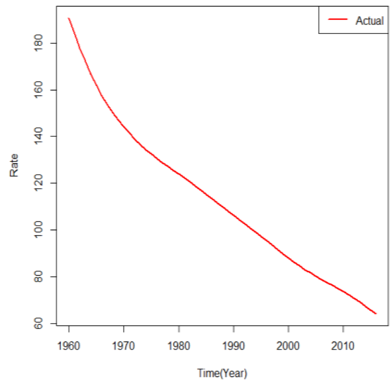

Fig. 2. A plot of IMR per 1,000 live births

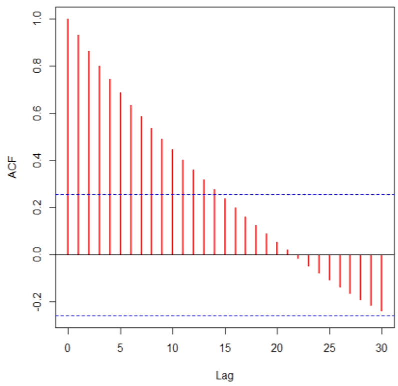

Fig. 3. A plot of ACF

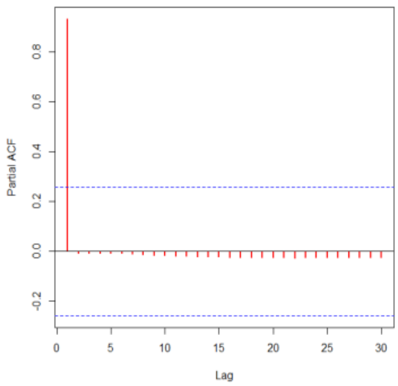

Fig. 4. A plot of PACF

Table 1. Detail of estimated parameters along with standard error (S.E) of the ARIMA(1, 2, 2) model

Feature	AR(1)	MA(1)	MA(2)
Parameters	0.9589	-0.8035	0.5029
S.E	0.0402	0.1231	0.1202

Table 2. Detail of estimated parameters along with S.E of the ARIMA(1, 2, 2) model

Time	Forecast	80% C.I		95% C.I	
		Low	High	Low	High
2018	59.54	59.41	59.67	59.34	59.73
2019	57.93	57.63	58.24	57.47	58.4
2020	56.39	55.8	56.98	55.48	57.3
2021	54.9	53.89	55.91	53.35	56.45
2022	53.47	51.89	55.04	51.05	55.88

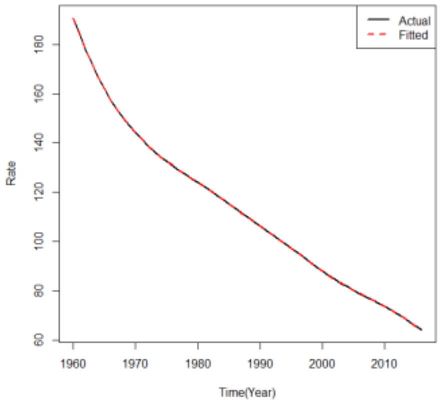

Fig. 5. A plot of actual & predicted ARIMA (1,2,2)

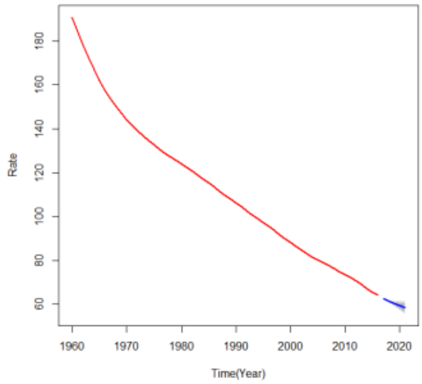

Fig. 6. A plot of forecasted ARIMA (1,2,2), C.I 80%, 95%

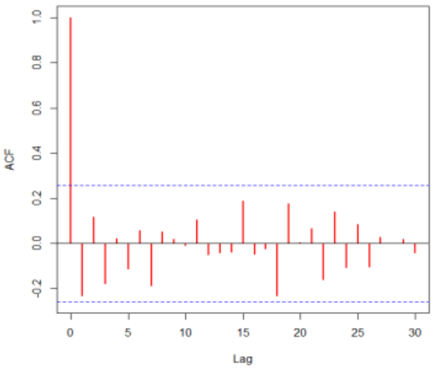

Fig. 7. A plot of ACF

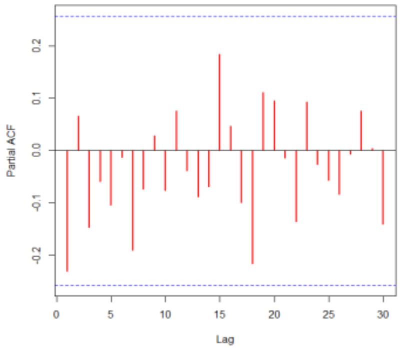

Fig. 8. A plot of PACF

3. RESULTS AND DISCUSSION

Globally, mortality rates have declined among children of all age groups over the past several years, but at the same time, a large proportion of children are still dying, mostly of preventable or treatable causes. These mortalities indicate that there is no or limited access to basic health care facilities by children and communities due to weakened primary healthcare systems. Many countries, including Pakistan, are facing many challenges to their health systems. On the other hand, demographic development needs to be improved and their primary health care systems strengthened. Low investment, poor planning, and a lack of understanding, on the other hand, are major causes that have led the foundation to ineffective primary healthcare systems.

Aziz and Hanif [20] conducted a cross-sectional study to underline the performance of the primary health care system in district Multan, a less developed city in Punjab, Pakistan, and concluded that a higher proportion of the respondents had uncertainties about the services provided by the basic health units. Due to the poor performance of the primary health care system, the current PDHS-2017-18 reflects higher death rates (neonatal 51/1,000, infant 73/1,000, and under five years, 85/1,000 live births) of children of all age groups in Punjab [10] million children can be saved by effective implementation of primary health care system-related policies and planning.

For instance, pneumonia and diarrhea are considered the leading causes of infectious mortality among children under five years old. In 2015, slightly less than half (49%) of global pneumonia deaths occurred in India, Nigeria, Pakistan, the Democratic Republic of the Congo, and Ethiopia collectively [21]. While 26·93% of diarrheal deaths occurred among children younger than 5 years, about 89·37% of diarrhoeal deaths occurred in South Asia and sub-Saharan Africa [22]. In Pakistan, 31% of children aged 6-11 months are affected by diarrhea, and only 71% of those children seek advice or treatment for diarrhea [10].

Nearly half of all deaths in children under 5 are associated with undernutrition. In 2018, an estimated 40 million children under the age of five were stunted (149 million), wasted (49 million), and overweight (40 million) [23]. Higher proportion of children belonging to Asia and Africa are stunted (55% in Asia versus 39% in Africa), wasted (68% in Asia versus

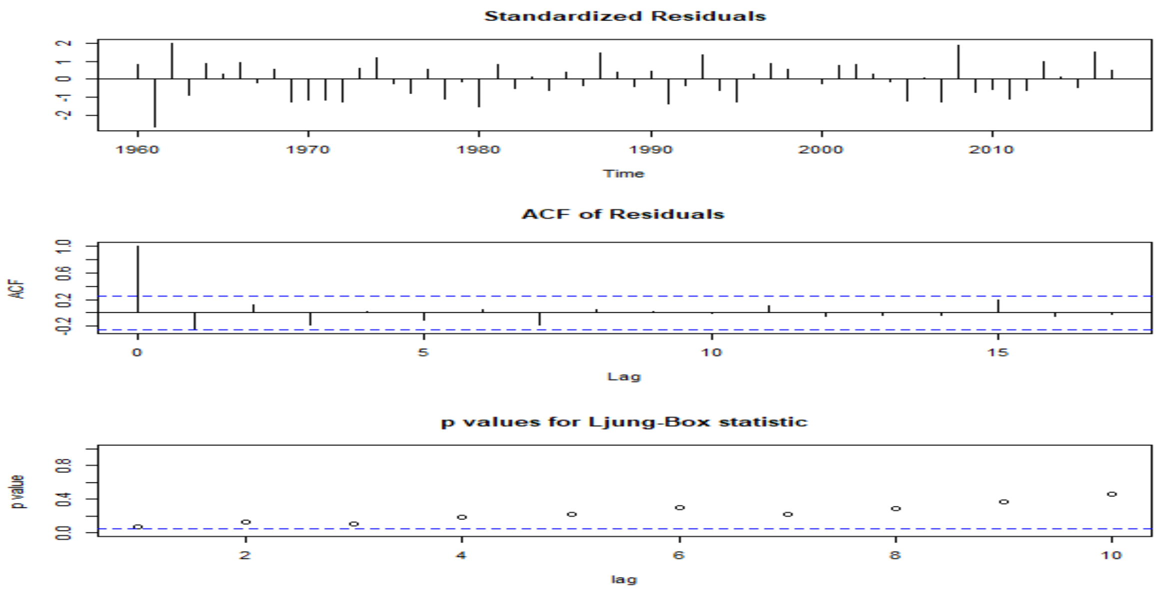

Fig. 9. Plot of ACF residual, Standardized residual and p-value for Ljung- Box statistic

28% in Africa) and overweight (47% in Asia versus 24% in Asia) respectively [23]. According to the 2017-18 PDHS, the prevalence of malnutrition among children in Pakistan is as follows: stunted 38%, wasted 7% and overweight 3% [10].

Huffman, Zehner [24] conducted a review study to underline the relationship between breast- feeding practices in the first month of life and neonatal mortality and found that breast- feeding helped to prevent the initial deaths by hypothermia and hypoglycaemia particularly among low birth weight and premature babies. Furthermore, the study revealed that most of the mortalities can be reduced by breast-feeding, especially exclusive breast feeding in developing countries, caused by acute respiratory tract infections, sepsis, meningitis, omphalitis, and diarrhea during the last neonatal period. Infants aged between zero and five months with no breast feeding have seven-fold increased risks of death from diarrhoea and five-fold increased risks of death from pneumonia, compared to their counterparts who are exclusively breastfed [25].

Globally approximately 80% of newborns die every year due to low birthweight and preterm or small for gestational age or both [26,27]. In Pakistan low birthweight are associated to child mortality, about 34% of live births to mother's under age 20 had a low birth weight compared 21% of births to mothers age 20-34. Punjab and Sindh have the highest percentage of babies (24% and 23%) with birthweight of less than 2.5 kilograms respectively [10].

In 2016, about 2.38 million deaths occurred from lower respiratory infections in children of all ages [22]. In Pakistan, more deaths are associated with acute respiratory infections of children under age 5 than with any other infectious disease [10]. According to PDHS-2017-18, the prevalence of symptoms of acute respiratory infection was highest (17%) among children of age six to eleven months. Children in Balochistan with symptoms of acute respiratory infection are less likely to seek advice or treatment (62%) compared to other provinces of Pakistan [10].

The median infant mortality rate is 109 per 1,000 live births, whereas a higher mortality rate (189.8) was reported in 1960. Every year, the infant mortality rate decreases gradually; it fell below 100/1,000 live births in 1993 and remained at 61.2/1,000 in 2017. The ARIMA(1, 2, 2) model is an adequate forecasting model, selected by using the Auto ARIMA function with a root mean square error of 0.1006. The infant mortality rate is expected to remain unchanged in 2018[59.54, C.I (59.34 - 59.73)], 2019 [57.93, C.I (57.47 - 58.40)], 2020 [56.39, C.I (55.48 - 57.30)], 2021 [54.90, C.I (53.35 - 56.45)] and 2022 [53.47, C.I (51.05 - 55.88)].

4. CONCLUSION

Although the mortality rate of all age groups among children is continuing to fall, it is not enough to achieve the targets of the Sustainable Development Goals (SDG) agenda, particularly in low and middle-income countries. On paper, Pakistan's health system seems to be impressive, but it is placed at the top with the highest mortality rate in the South Asian region.

Pakistan should learn a lesson from Sri Lanka with IMR 9/1,000 live births in the region. Pakistan needs smart, effective, and proactive strategies to reduce mortality caused by preventable and treatable infections in order to achieve the proposed SDG 2030 target of reducing neonatal mortality to at least as low as 12 deaths per 1,000 live births and under-5 mortality to at least as low as 25 deaths per 1,000 live births. The ARIMA(1, 2, 2) model is an adequate forecasting model with forecasting error 0.1006. A decreasing trend is expected in IMR per 1,000 live births in Pakistan. These statistical results will serve as a guide to understanding the trend and pattern of infant child mortality and timely intervention to ultimately achieve better health outcomes as well as the targets of SDG 2030.The authors refer [28-77] to the readers for new developments in the field of statistics.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. WHO: World Health Organization, Infant mortality situation and trends; 2017. Available:https://www.who.int/gho/child_health/mortality/neonatal_infant_text/en/
2. UNIGME: ‘Levels & Trends in Child Mortality: Report 2018, Estimates developed by the United Nations Inter-agency Group for Child Mortality Estimation’, United Nations Children’s Fund, New York; 2018.
3. UNIGME: Levels & Trends in Child Mortality: Report 2017: Estimates Developed by the UN Inter-Agency Group for Child Mortality Estimation: United Nations Children's Fund, 2017.
4. Gallup: Gallup report of infant mortality 1980-2018, Pakistan; 2018. Available:http://gallup.com.pk/wp-content/uploads/2018/04/Infant-mortality-PR-1.pdf
5. Khadka KB, Lieberman LS, Giedraitis V, Bhatta L, Pandey G. The socio-economic determinants of infant mortality in Nepal: analysis of Nepal Demographic Health Survey, 2011. BMC Pediatrics. 2015;15:152.
6. Liu Y, Chen Y, Wang D: Economic and socioeconomic determinants of infant mortality: A cross-country investigation; 2015.
7. Lamichhane R, Zhao Y, Paudel S, Adewuyi EO: Factors associated with infant mortality in Nepal: a comparative analysis of Nepal demographic and health surveys (NDHS) 2006 and 2011. BMC Public Health. 2017;17:53.
8. Zahid GM. Mother's health-seeking behaviour and childhood mortality in Pakistan. The Pakistan Development Review. 1996;719-31.
9. Iram U, Butt MS: Socioeconomic determinants of child mortality in Pakistan: Evidence from sequential probit model. International Journal of Social Economics. 2008;35:63-76.
10. NIPS: National Institute of Population Studies (NIPS) [Pakistan] and ICF. 2019. Pakistan Demographic and Health Survey 2017-18. Islamabad, Pakistan, and Rockville, Maryland, USA: NIPS and ICF; 2017-18.
11. Helova A, Hearld KR, Budhwani H: Associates of neonatal, infant and child mortality in the Islamic Republic of Pakistan: a multilevel analysis using the 2012–2013 demographic and health surveys. Maternal and Child Health Journal. 2017;21:367-75.
12. Shumway RH, Stoffer DS. Time series analysis and its applications: with R examples: Springer; 2017.
13. Carnes BA, Olshansky SJ, Grahn D: Continuing the search for a law of mortality. Population and Development Review 1996:231-64.
14. Willemse W, Koppelaar H. Knowledge elicitation of Gompertz'law of mortality. Scandinavian Actuarial Journal. 2000, 2000:168-79.
15. Keyfitz N. Choice of function for mortality analysis: Effective forecasting depends on a minimum parameter representation. Theoretical Population Biology. 1982;21:329-52.
16. Carroll GR. A stochastic model of organizational mortality: Review and reanalysis. Social Science Research. 1983; 12:303-29.
17. Lin XS, Liu X. Markov aging process and phase-type law of mortality. North American Actuarial Journal. 2007;11:92-109.
18. Brockwell PJ, Davis RA, Calder MV: Introduction to time series and forecasting: Springer; 2002.
19. Van Weel C, Kassai R, Qidwai W, Kumar R, Bala K, Gupta PP, Haniffa R, Hewageegana NR, Ranasinghe T, Kidd M: Primary healthcare policy implementation in South Asia. BMJ Global Health. 2016;1:e000057.
20. Aziz SZ, Hanif I: Primary care and health system performance in Pakistan: A study of basic health units of South Punjab. J Pak Med Assoc. 2016;66:1632-6.
21. McAllister DA, Liu L, Shi T, Chu Y, Reed C, Burrows J, Adeloye D, Rudan I, Black RE, Campbell H. Global, regional, and national

estimates of pneumonia morbidity and mortality in children younger than 5 years between 2000 and 2015: a systematic analysis. The Lancet Global Health. 2019;7:e47-e57.

22. Naghavi M, Abajobir AA, Abbafati C, Abbas KM, Abd-Allah F, Abera SF, Aboyans V, Adetokunboh O, Afshin A, Agrawal A: Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet. 2017; 390:1151-210.
23. UNICEF: United Nations Children’s Fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2019 Edition of the Joint Child Malnutrition Estimates. Geneva: World Health Organization; 2019.
24. Huffman SL, Zehner ER, Victora C: Can improvements in breast-feeding practices reduce neonatal mortality in developing countries? Midwifery. 2001;17:80-92.
25. Victora CG, Smith PG, Vaughan JP, Nobre LC, Lombardi C, Teixeira AMB, Fuchs SC, Moreira LB, Gigante LP, Barros FC: Infant feeding and deaths due to diarrhea: a case-control study. American Journal of Epidemiology. 1989;129:1032-41.
26. Katz J, Lee AC, Kozuki N, Lawn JE, Cousens S, Blencowe H, Ezzati M, Bhutta ZA, Marchant T, Willey BA: Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. The Lancet. 2013; 382:417-25.
27. Organization WH: Survive and thrive: transforming care for every small and sick newborn: key findings. Survive and thrive: transforming care for every small and sick newborn: key findings; 2018.
28. Jamal F, Chesneau C, Aidi K, Ali A. Theory and application of the power ailamujia distribution. Journal of Mathematical Modeling. 2021;9(3):391-413.
29. Afify AZ, Cordeiro GM, Ibrahim NA, Jamal F, Elgarhy M, Nasir MA. The marshall-olkin odd burr III-G family: Theory, estimation, and engineering applications. IEEE Access. 2021;9:4376-4387.
30. Abdulhakim A. Al-Babtain, Rehan AK Sherwani, Ahmed Z. Afify, Khaoula Aidi, M. Arslan Nasir, Farrukh Jamal, Abdus Saboor. The extended Burr-R class: Properties, applications and modified test for censored data. 2021;6(3):2912-2931.
31. Ramadan A ZeinEldin, Christophe Chesneau, Farrukh Jamal, Mohammed Elgarhy , Abdullah M. Almarashi, Sanaa Al-Marzouki. Generalized truncated frechet generated family distributions and their applications. 2021;126(2):791-819.
32. Naeem S, Ali A, Chesneau C, Tahir MH, Jamal F, Sherwani RAK, Ul Hassan M. The classification of medicinal plant leaves based on multispectral and texture feature using machine learning approach. Agronomy. 2021;11:263.
33. Al-Marzouki S, Jamal F, Chesneau C, Elgarhy M. Half logistic inverse lomax distribution with applications. Symmetry. 2021;13(2):309.
Available:https://doi.org/10.3390/sym13020309
34. Al-Marzouki, Sanaa, Christophe Chesneau, Sohail Akhtar, Jamal Abdul Nasir, Sohaib Ahmad, Sardar Hussain, Farrukh Jamal, Mohammed Elgarhy, El-Morshedy M. Estimation of finite population mean under PPS in presence of maximum and minimum values. AIMS Mathematics. 2021;6(5):5397-5409.
35. Bantan Rashad, Amal S Hassan, Ehab Almetwally, Elgarhy M, Farrukh Jamal, Christophe Chesneau, Mahmoud Elsehetry. Bayesian analysis in partially accelerated life tests for weighted lomax distribution. CMC-Computers Materials & Continua. 2021; 68(3):2859-2875.
36. Khan Sherwani, Muhammad Waqas, Nadia Saeed, Muhammad Farooq, Muhammad Ali Raza, Farrukh. Transmuted inverted kumaraswamy distribution: Theory and applications Rehan Ahmad. Jamal Punjab University Journal of Mathematics. 2021;53(3):29-45.
37. Aqib Ali, Wali Khan, Naeem Mashwani, Uddin Samreen, Muhammad Irfan, Wiyada Kumam, Poom Kumam, Hussam Alrabaiah, Farrukh Jamal, Christophe Chesneau. COVID-19 infected lung computed tomography segmentation and supervised classification approach. Computers, Materials, & Continua. 2021;391-407.
38. Farooq M, Sarfraz S, Chesneau C, Ul Hassan M, Raza MA, Sherwani RAK, Jamal F. Computing expectiles using k-nearest neighbours approach. Symmetry. 2021;13:645.
Available:https://doi.org/10.3390/sym13040645
39. Abdullah Ali H. Ahmadini, Wali Khan Mashwani, Rehman Ahmad Khan Sherwani, Shokrya S. Alshqaq, Farrukh Jamal, Miftahuddin Miftahuddin, Kamran

Abbas, Faiza Razaq, Mohammed Elgarhy, Sanaa Al-Marzouki. Estimation of constant stress partially accelerated life test for fréchet distribution with type-I censoring. Mathematical Problems in Engineering. 2021;Article ID 9957944:8.

40. Jamal F, Chesneau C, Bouali DL, Ul Hassan M. Beyond the Sin-G family: The transformed Sin-G family. PLoS ONE. 2021;16(5):e0250790. Available:https://doi.org/10.1371/journal.pone.0250790

41. Bantan R, Elsehetry M, Hassan AS, Elgarhy M, Sharma, D, Chesneau C, Jamal F. A two-parameter model: Properties and estimation under ranked sampling. Mathematics. 2021; 9:1214. Available:https://doi.org/10.3390/math9111214

42. Almarashi AM, Khan K, Chesneau C, Jamal F. Group acceptance sampling plan using marshall–olkin kumaraswamy exponential (MOKw-E) distribution. Processes. 2021; 9:1066. Available:https:// doi.org/10.3390/pr9061066

43. Muhammad Mohsin, Shafaqat Mehmood, Farrukh Jamal, Muhammad Mushahid Anwer. Modeling and forecasting of declining area and production of mango orchards in district Bahawalpur, Pakistan: A case of tehsil ahmedpur east. J Agric. Res. 2021;59(2):197-212.

44. Muhammad Rasheed, Khadija Noreen, Rashid Ahmed MH Tahir, Farrukh Jamal. Some useful classes of minimal weakly balanced neighbor designs in circular blocks of two different sizes, Communications in Statistics - Theory and Methods; 2021. DOI: 10.1080/03610926.2021.1975135

45. Bantan, Rashad AR, Christophe Chesneau, Farrukh Jamal, Ibrahim Elbatal, Mohammed Elgarhy. The truncated burr XG family of distributions: Properties and applications to actuarial and financial data. Entropy. 2021;23(8):1088.

46. Algarni Ali, Abdullah M Almarashi, Farrukh Jamal, Christophe Chesneau, aMohammed Elgarhy. Truncated inverse lomax generated family of distributions with applications to biomedical data. Journal of Medical Imaging and Health Informatics. 2021;11(9):2425-2439.

47. Bantan, Rashad AR, Farrukh Jamal, Christophe Chesneau, Mohammed Elgarhy. Theory and applications of the unit gamma/gompertz distribution. Mathematics. 2021;9(16):1850.

48. Bantan RA, Jamal F, Chesneau C, Elgarhy M. Type II Power Topp-Leone Generated Family of Distributions with Statistical Inference and Applications. Symmetry. 2020;12(1):75.

49. Al-Marzouki S, Jamal F, Chesneau C, Elgarhy M. Type II topp leone power lomax distribution with applications. Mathematics. 2020;8(1):4.

50. Jamal F, Chesneau C, Elgarhy M. Type II general inverse exponential family of distributions. Journal of Statistics and Management Systems. 2020;23(3):617-641.

51. Chesneau C, Jamal F. On a new special member of the Weibull-X family of distributions. Eurasian Bulletin of Mathematics (ISSN: 2687-5632). 2020;3(2):56-72.

52. Shah MAA, Mashwani WK, Kumam W, Kumam P, Chesneau C, Jamal F, Khan HU. Application of mixed sampling to real life data: A case study on socio-economic determinants by using SEM and CFA Techniques. Mathematics. 2020;8(3):337.

53. Bantan RA, Zeineldin RA, Jamal F, Chesneau C. Determination of the factors affecting king Abdul Aziz University Published Articles in ISI by Multilayer Perceptron Artificial Neural Network. Mathematics. 2020;8(5):766.

54. Al-Marzouki S, Jamal F, Chesneau C, Elgarhy M. Erratum: Al-Marzouki, S., et al. Type II Topp Leone Power Lomax Distribution with Applications. Mathematics 2020, 8, 4. Mathematics. 2020;8(6):871.

55. Bantan RA, Elgarhy M, Chesneau C, Jamal F. Estimation of entropy for inverse lomax distribution under multiple censored data. Entropy. 2020;22(6):601.

56. Ali A, Qadri S, Mashwani WK, Brahim Belhaouari S, Naeem S, Rafique S, Anam S. Machine learning approach for the classification of corn seed using hybrid features. International Journal of Food Properties. 2020;23(1):1110-1124.

57. Ali A, Qadri S, Khan Mashwani W, Kumam W, Kumam P, Naeem S, Sulaiman M. Machine learning based automated segmentation and hybrid feature analysis for diabetic retinopathy classification using fundus image. Entropy. 2020;22(5):567.

58. Naeem S, Ali A, Qadri S, Mashwani WK, Tairan N, Shah H, Anam S. Machine-learning based hybrid-feature analysis for liver cancer classification using fused (MR and CT) images. Applied Sciences. 2020;10(9):3134.

59. Jamal F, Reyad HM, Ahmed SO, Ali Shah SMA. Mathematical properties and applications of minimum gumbel burr distribution. NED University Journal of Research. 2020;17(2):1-14.

60. Jamal F, Bakouch HS, Nasir MA. Odd burr III G-Negative binomial family with application. Journal of Testing and Evaluation. 2020;49(5):1-21.
61. Handique L, Jamal F, Chakraborty S. On a family that unifies Generalized Marshall-Olkin and Poisson-G family of distribution. Accepted Manuscript, arXiv preprint arXiv:2006.05816; 2020.
62. Bantan RA, Jamal F, Chesneau C, Elgarhy M. On a new result on the ratio exponentiated general family of distributions with applications. Mathematics. 2020;8(4):598.
63. Bantan RA, Chesneau C, Jamal F, Elgarhy M. On the Analysis of New COVID-19 cases in pakistan using an exponentiated version of the M family of distributions. Mathematics. 2020;8(6):953.
64. Almarashi AM, Badr MM, Elgarhy M, Jamal F, Chesneau C. Statistical inference of the half-logistic inverse rayleigh distribution. Entropy. 2020;22(4):449.
65. Almarashi AM, Elgarhy M, Jamal F, Chesneau C. The exponentiated truncated inverse weibull-generated family of distributions with applications. Symmetry. 2020;12(4):650.
66. Chesneau, C, Tomy L, Gillariose J, Jamal F. The inverted modified Lindley distribution. Journal of Statistical Theory and Practice. 2020;14(3):1-17.
67. Chakraborty S, Handique L, Jamal F. The Kumaraswamy Poisson-G family of distribution: its properties and applications. Annals of Data Science. 2020;7(4):1-19.
68. Nasir MA, Tahir MH, Chesneau C, Jamal F, Shah MAA. The odds generalized gamma-G family of distributions: Properties, regressions and applications. Statistica. 2020;80(1):3-38.
69. Reyad H, Jamal F, Özel G, Othman S. The Poisson exponential-G family of distributions with properties and applications. *Journal of* Statistics and Management Systems. 2020;23(7):1-24.
70. Badr MM, Elbatal I, Jamal F, Chesneau C, Elgarhy M. The transmuted odd fréchet-G family of distributions: Theory and applications. Mathematics. 2020;8(6):958.
71. Aldahlan MA, Jamal F, Chesneau C, Elgarhy M, Elbatal I. The truncated Cauchy power family of distributions with inference and applications. Entropy. 2020;22(3):346.
72. Al-Marzouki S, Jamal F, Chesneau C, Elgarhy M. Topp-leone odd fréchet generated family of distributions with applications to COVID-19 data sets. Computer Modeling in Engineering & Sciences. 2020;125(1):437-458.
73. Bantan RA, Jamal F, Chesneau C, Elgarhy M. Type II power topp-leone generated family of distributions with statistical inference and applications. Symmetry. 2020;12(1):75.
74. Jamal F, Chesneau C, Elgarhy M. Type II general inverse exponential family of distributions. Journal of Statistics and Management Systems. 2020;23(3):617-641.
75. Al-Babtain AA, Elbatal I, Chesneau C, Jamal F. Box-Cox gamma-G family of distributions: Theory and applications. Mathematics. 2020; 8(10):1801.
76. Bantan RA, Chesneau C, Jamal F, Elgarhy M, Tahir MH, Ali A, Anam S. Some new facts about the unit-rayleigh distribution with applications. Mathematics. 2020;8(11):1954.
77. Gillariose J, Tomy L, Jamal F, Chesneau C. The Marshall-olkin modified lindley distribution: Properties and applications. Journal of Reliability and Statistical Studies. 2020;13(1):177-198.

APPENDIX –A

R-Coding For Fitting ARIMA Model

```
library(forecast)
data<-read.csv(file.choose(),header=TRUE)
head(data)
data.ts<-ts(data$Value,start=min(data$year), end=max(data$year))
boxplot(data$Value, col=2, lwd=2, lag=30, main="Fig.1: Box Plot of IMR")
plot(data.ts, main="Fig.2:A Plot of IMR per 1,000 live births", xlab = "Time(Year)", ylab = "Rate", col=2,lwd=2,lty=1)
legend("topright", expression(data.ts=Actual),lty=1,col=2,lwd=2)
acf(data$Value, col=2, lwd=2, lag=30, main="Fig.3: A Plot of ACF")
pacf(data$Value, col=2, lwd=2, lag=30, main="Fig.4: A Plot of PACF")
fit<-auto.arima(data.ts)
fit
plot(data.ts, main="Fig.5:A Plot of Actual & Predicted ARIMA(1,2,2)", xlab = "Time(Year)", ylab = "Rate", col=1,lwd=2,lty=1)
lines(fitted(fit), col=2,lwd=2,lty=2)
legend("topright", c(expression(data.ts=Actual),expression(fit=Fitted)),lty=c(1:2), col=c(1:2), lwd=c(2,2))
forecast<-forecast(fit,h=5)
forecast
plot(forecast, main="Fig.6:A Plot of Forecasted, ARIMA(1,2,2), C.I 80%, 95%",xlab = "Time(Year)", ylab = "Rate", col=2,lwd=2)
fit_resid=residuals(fit)
Box.test(fit_resid, lag=10,type="Ljung")
acf(fit_resid,col=2, lwd=2, lag=30, main="Fig.7: A Plot of ACF")
pacf(fit_resid,col=2, lwd=2, lag=30, main="Fig.8: A Plot of PACF")
accuracy(forecast)
tsdiag(fit, main=”Fig 9”)
```

Augmented Dickey-Fuller Test for Stationary

```
Library (tseries)
adf.test(data.ts)
```
