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Research Paper

Analyzing Bangladesh's Present Patterns in Population Growth and Prediction By ARIMA and Exponential Smoothing Model

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Abstract— Bangladesh has the highest population density in the entire world. It ranks as the eighth largest population nation in the world in South Asia with a population of about 170 million. Bangladesh's rapid population growth is one of the most significant problems. Currently one of the most populous nations and the country's major concern is its enormous population. An exponential smoothing and ARIMA (1,1,1) model is used to forecast Bangladesh's population from 2022 to 2070 using actual data from 1950 to 2021. The population in 2070 is predicted to be between 277 million and 306 million according to our analysis, which used the ARIMA (1,1,1) models and exponential smoothing. We used ARIMA and exponential smoothing models to analyse our time series data, which were chosen based on Bayesian information criterion (BIC) with P-values less than 5% and graphical representation of ACF and PACF plots. These models are used to draw numerical pictures of future population growth and forecast.

Keywords— ARIMA, Exponential Smoothing model, Population Growth, ACF and PACF

1. Introduction

Despite the fact that population is the most important factor in the world, estimated population has converted one of the world's most thoughtful problems. A country's population directly influences its economy, politics, culture, education, and ecological circumstances, as well as the cost of natural resource exploration [1]. Every government's and joint sector's future actions always necessitate an accurate understanding of the future shape of various livelihoods such as population, demand, wealth, and consumption [2, 3]. Mathematicians and statisticians use historical data to analyse the behaviour of the associated variables, and they then use the results of their analysis to predict how the variables will behave in the future [3, 4]. Environmental, social, and economic development are all impacted negatively by human population growth, which is a major source of concern. A broad field of interdisciplinary science known as mathematical analysis and modeling expenditures mathematical and computational methods to model and explain phenomena that occur in the real world [5]. When the present is defined in relation to the past and the future is defined in terms of the present, population models are used to describe a common human approach to reality. Many differential equations are solved in order to understand how an primary physical process that the equation is supposed to model behaves [6, 7]. Mathematical models include things like differential equations, statistical models, and dynamical systems [8]. An analysis of population dynamics typically involves the use of a population model. Models enable us to grasp the operation of intricate interactions and processes [9] A practical way to understand how facts change over time or in relation to one another might be to model natural dynamic interactions [1].

In this study, we use an exponential smoothing model and an autoregressive integrated moving average model to summarize Bangladesh's population growth. Using our two-choice model, our analysis predicts that Bangladesh's population in 2070 will be somewhere between 306 million and 277 million. Our results show that Bangladesh's projected population is very similar to current population trends.

2. Methodology

2.1 Data Source

The yearly periodic data on carbon dioxide discharges in Bangladesh from 1946 to 2021 were considered in this study. The annual data secondary data were gathered from the World Data Bank (https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=BD) and our world in data (https://ourworldindata.org/)

2.2 ARIMA Model

ARIMA is an established method for analysing non-stationary time - series data. Unlike most regression models,

the ARIMA structure sanctions time series to be explicated by their past or lag values as well as stochastic error terms [10].These models are commonly referred to as ARIMA models because they combine autoregressive (AR), integration (I) - referring to the contrary process of differencing - and moving average (MA) processes to produce the forecast [11].

The Autoregressive Integrated Moving Average model is symbolized by $ARIMA\ (p,d,q)$, here "p" represents the direction of the auto regressive route, "d" represents the direction of the data stationary process, and "q" characterizes the direction of the moving average process. The common structure of the $ARIMA\ (p,d,q)$ can be chosen to write as [12].

$$\Delta^d y_t = \delta + \theta_1 \Delta^d y_{t-1} + \theta_2 \Delta^d y_{t-2} + \ldots. + \theta_p y_{t-p} + e_{t-1} \alpha e_{t-1} - \alpha_2 e_{t-2} \alpha_q e_{t-2}$$

……..(1)

Here, Δ^d indicates differencing of order d, i.e., $\Delta y_t = y_t - y_{t-1}$, $\Delta^2 y_t = \Delta y_t - \Delta y_{t-1}$ and so forth. $y_{t-1} \ldots y_{t-p}$ are first remarks (lags), $\delta, \theta_1, \ldots, \theta_p$ are limitations (constant and coefficient) to be projected parallel to regression coefficients of the Auto Regressive method (AR) of order "p" symbolized by $AR(p)$ and can be expressed as,

$$Y = \delta + \theta_1 y_{t-1} + y_{t-2} + \cdots \ldots. + \theta_p y_{t-p} + e_t \ldots\ldots\ldots\ldots (2)$$

here, e_t is forecast error, expected to be independently dispersed across period with mean θ and variance $\theta_2 e, e_{t-1}, e_{t-2} \ldots . e_{t-p}$ are past forecast errors, $\alpha_1 \ldots\ldots \alpha_q$ ⋯ are moving average (MA) coefficient.

.Whereas MA method of direction q (i.e.) $MA\ (q)$ can be expressed as,

$$Y_t = e_t - \alpha_1 e_{t-1} - \alpha_2 e_{t-2} - \cdots - \alpha_q e_{t-q}$$

……...……...(3)

2.3 Exponential Smoothing

Exponential smoothing is among the most fundamental techniques for modelling time-series data, in which previous observations are weighted to rapidly decreasing values over time. The selecting models are proposed for modelling population growth and projected population size [13, 14].

For single exponential smoothing, let $\{y_t\}$ represent raw observations and $\{s_t\}$ represent the best estimate of trend at time t. Then $s_0 = y_0$, $s_t = \alpha y_t + (1-\alpha).(s_{t-1})$ where $\alpha \in (0,1)$ denotes the data smoothing factor. Let the raw observations be denoted by $\{y_t\}$, the smoothed values by $\{s_t\}$ and $\{b_t\}$ represents the best estimate of trend at time t for double exponential smoothing [13,14]. Then,

$$s_1 = y_1$$
$$b_1 = y_2 - y_1$$
$$s_t = \alpha x_t + (1-\alpha).(s_{t-1} - b_{t-1})$$
$$b_t = \beta(s_t - s_{t-1}) + (1-\beta) b_{t-1}$$

where $\alpha \in (0,1)$ denotes the data smoothing factor and $\beta \in (0,1)$ represents the trend smoothing factor. F_{N+m} is calculated for the forecast at $t = (N+m)$ days.

$$F_{N+m} = s_t + m b_t$$

3. Results and Discussion

3.1 Data Analysis

In this paper, to analyse population growth in Bangladesh by using time series data, we applied two time series data analysis method ARIMA and exponential smoothing model according to information of table-1. From table-1 we get our model selection criteria Bayesian Information Criterion (BIC). In figure-1 and figure-2 we represent Auto-correlation Function (ACF) Plot and Partial Auto-correlation Function (PACF) Plot also in figure-3 and figure-4 we plot ACF– Residuals and PACF– Residuals; where Significance Limit Alpha = 0.05 respectively. The ACF and PACF figures, as well as the residuals- ACF and residuals- PACF figures, show that there is no vital spike in the distinctive sequence, indicating that there are no noticeable consequences of Auto-Regressive and Moving Average in the distinctive sequence, indicating that the population secretion series is standing with lacking distinction. We also observe that Figure 5&6 where we investigate the relationship between Residuals vs Data Order for Annual Population and Residuals vs forecast value. After declaring the sequences stationary, various parametric arrangements of the exponential smoothing model were applied to analyse the 76-year data (1946 to 2021) of population growth and the above-mentioned selection criteria. Table-2, 3, repent the Parameter Estimates by exponential smoothing model and Model Statistics information respectively. In table -4 we represent Metric value in Sample (Estimation) One-Step-Ahead Forecast for ARIMA and exponential smoothing model according to our analysis.

3.2 Forecast

Projected value of population growth in Bangladesh for out-of-sample forecast accuracy evaluation are shown - on table 5 and graph-7 represents Population growth in Bangladesh by ARIMA and simple exponential smoothing model for Time Series Forecasting Chart 95.0% Prediction Intervals from 2022 to 2046. With a projection range of 23 years, i.e., 2022 – 2046; Figure 7 and Table 5, noticeably indicate that population growth in Bangladesh are continuously increasing. our analysis predicts that Bangladesh's population in 2070 will be somewhere between 306 million and 277 million. Our results show that Bangladesh's projected population is very similar to current population trends.

Figures and Tables

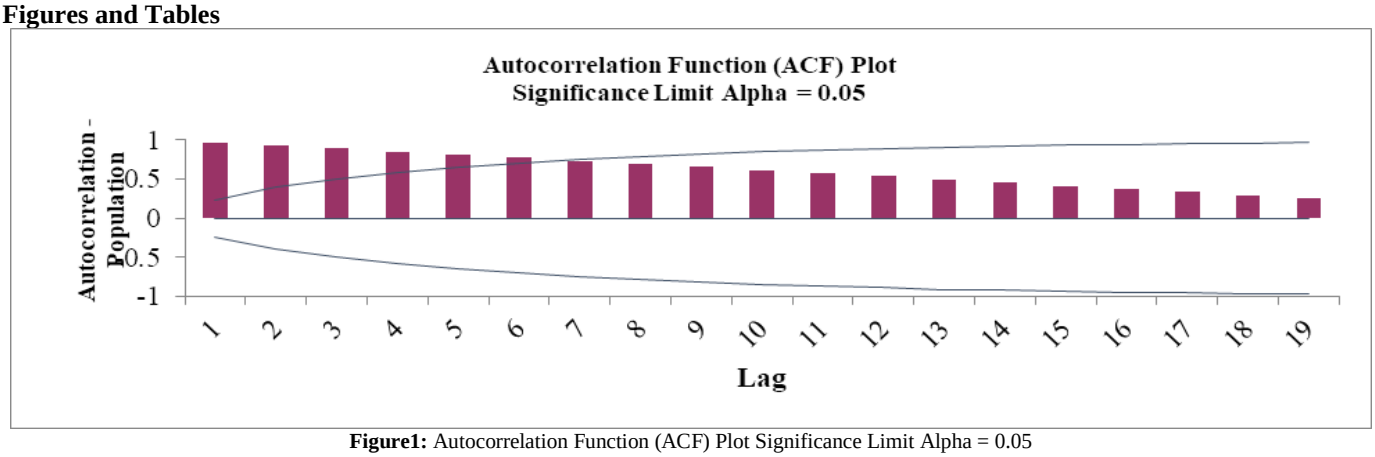

Figure1: Autocorrelation Function (ACF) Plot Significance Limit Alpha = 0.05

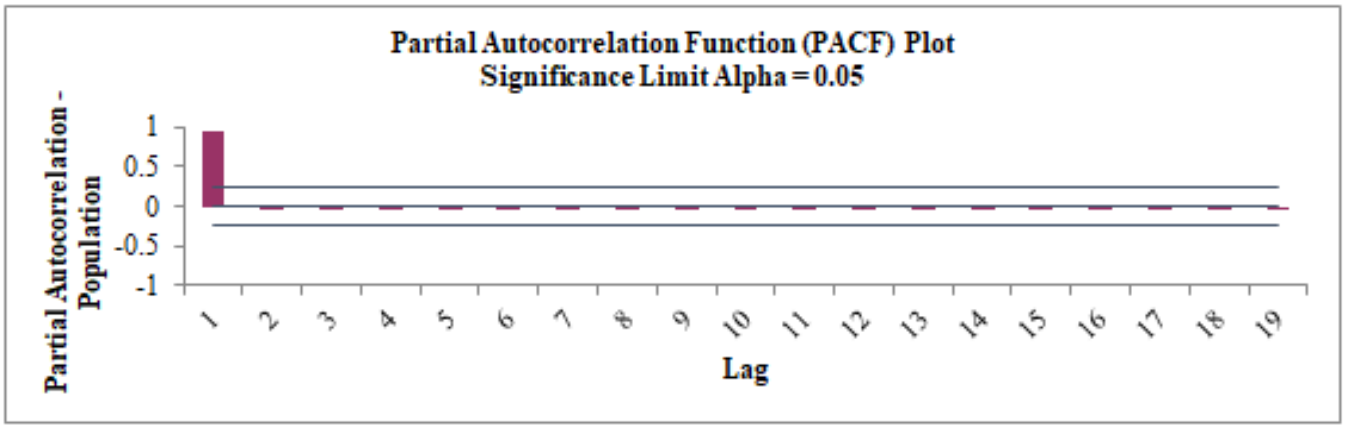

Figure-2: Partial Autocorrelation Function (PACF) Plot; Significance Limit Alpha = 0.05

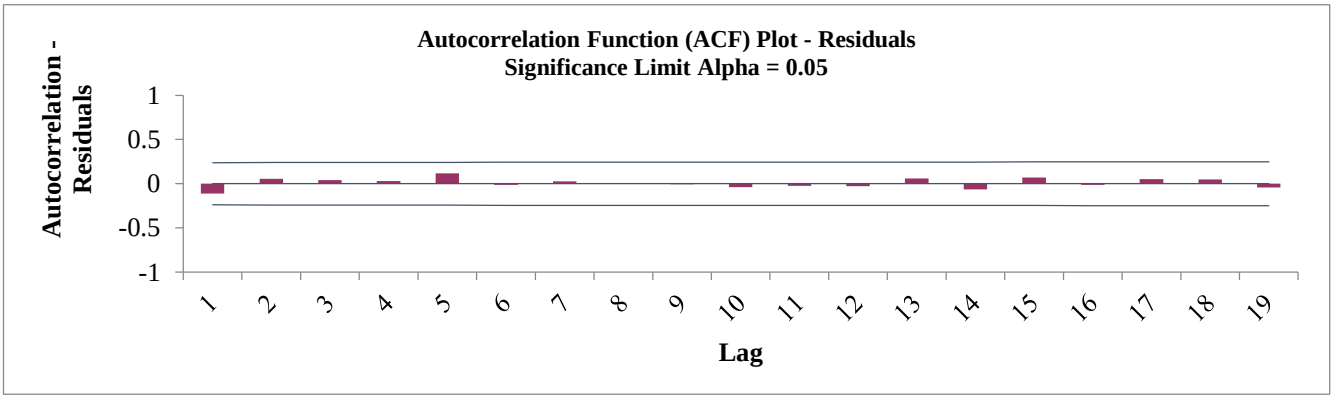

Figure-3: Autocorrelation Function (ACF) Plot – Residuals; Significance Limit Alpha = 0.05

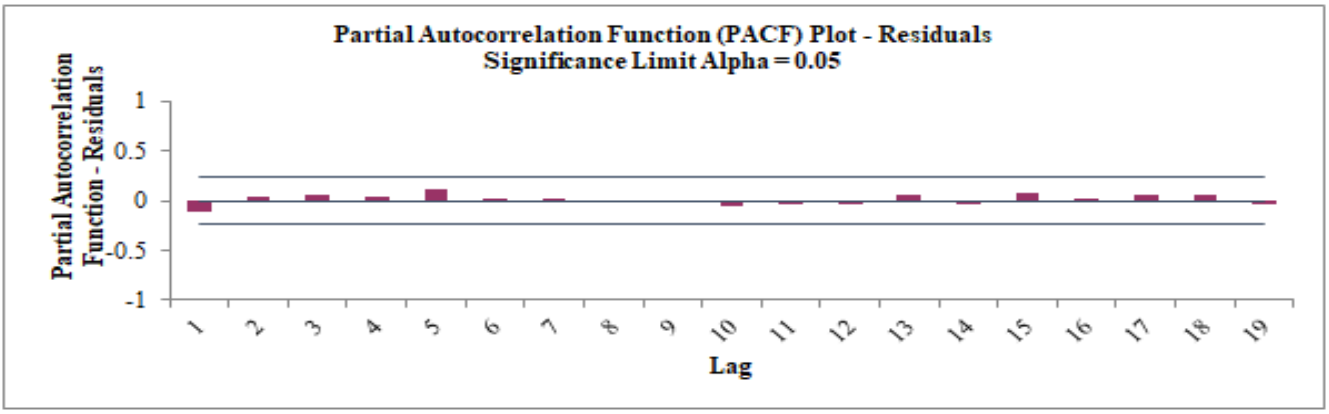

Figure-4: Partial Autocorrelation Function (PACF) Plot – Residuals; Significance Limit Alpha = 0.05

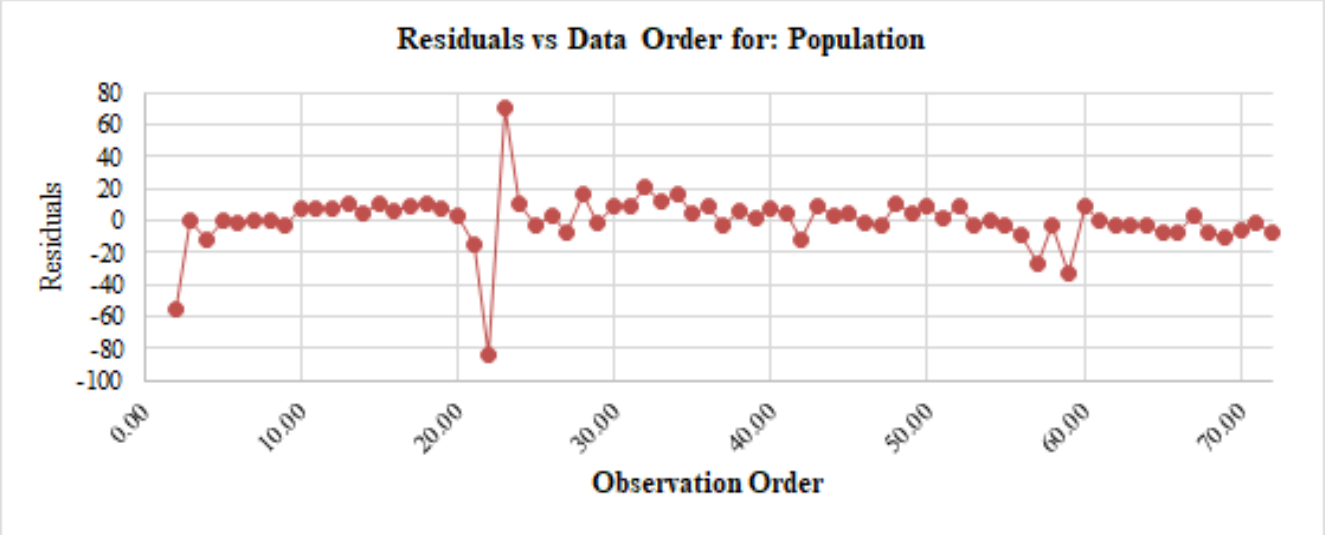

Figure-5: Observe Residuals vs Data Order for Annual Population

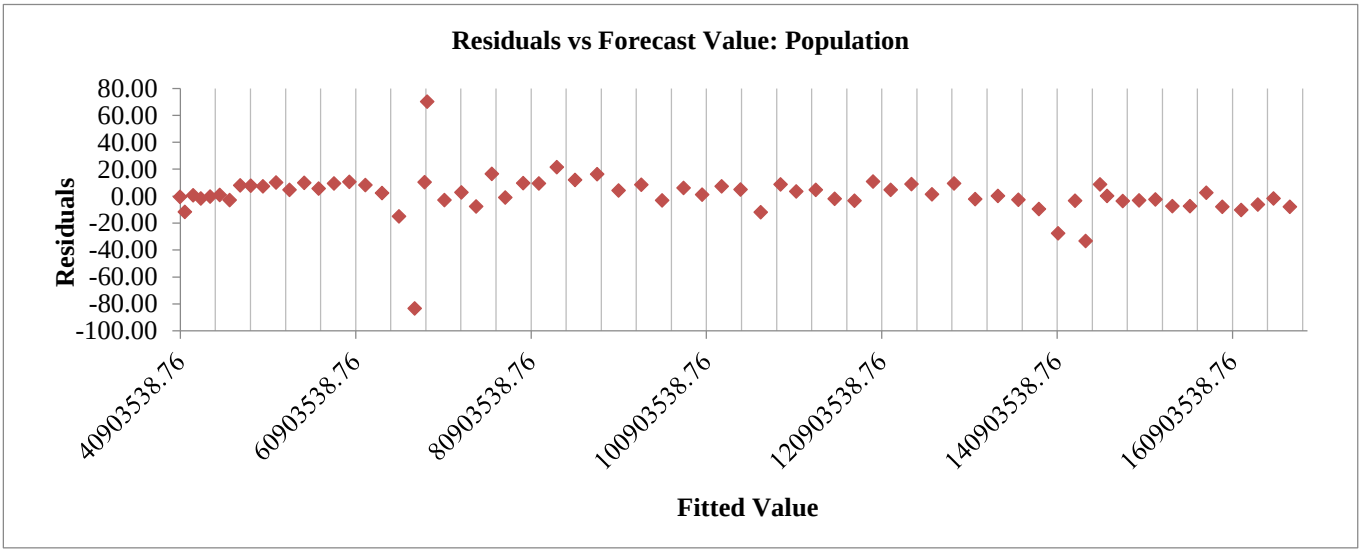

Figure-6: Observe Residuals Vs Forecast Value for Annual Population Data

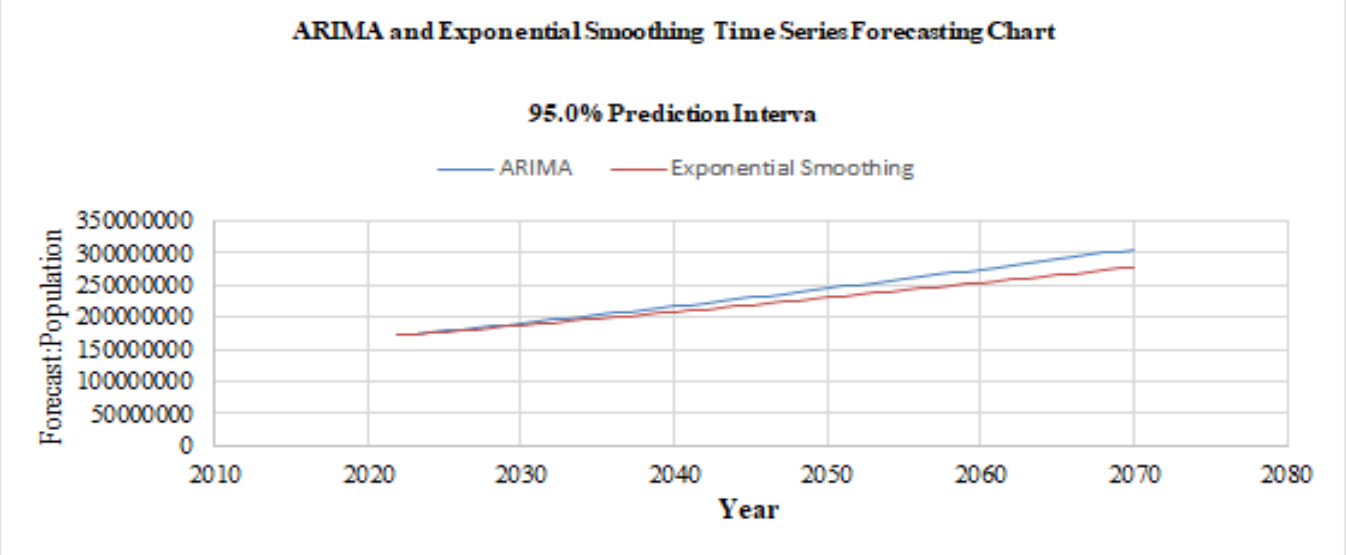

Figure-7: ARIMA and Exponential Smoothing Time Series Forecast Chart 95.0% Prediction Intervals

Table-1.1: Identification information of model selection for Exponential Smoothing ARIMA Model

ARIMA Model Summary	
AR Order (p)	1
I Order (d)	1
MA Order (q)	1
SAR Order (P)	0
SI Order (D)	0
SMA Order (Q)	0
Seasonal Frequency	1
Include Constant	1
No. of Predictors	0
Model Selection Criterion	BIC
Box-Cox Transformation	Rounded Lambda
Lambda	0.5
Threshold	0

Table-1.2: Identification information of model selection for Exponential Smoothing

Exponential Smoothing Model Information	
Seasonal Frequency	1
Model Selection Criterion	BIC
Box-Cox Transformation	Rounded Lambda
Lambda	0.5
Threshold	0

Table-2.1: Parameter Estimation by ARIMA method.

Parameter Estimates				
Term	**Coefficient**	**SE Coefficient**	**T**	**P**
AR_1	0.698736044	0.085366201	8.18516	**0.0000**
MA_1	-0.990097722	0.057461034	17.23077	**0.0000**
Const:Trend	185.0589125	11.91425924	15.53256	**0.0000**

Table-2.2: Parameter Estimation by Exponential Smoothing method.

Parameter Estimates	
Term	**Coefficient**
alpha (level smoothing)	0.9999
beta (trend smoothing)	0.9999
l (initial level)	12474.71863
b (initial trend)	129.3775858

Table-3: Model statistics information for ARIMA and Exponential Smoothing

Model Statistics	**ARIMA**	**Exponential Smoothing**
No. of Observations	72	72
DF	68	68
StDev	15.83889261	20.46723
Variance	250.8705191	418.9073
Log-Likelihood	-299.090654	-369.258
AICc	606.7873687	749.4244
AIC	606.1813081	748.5153
BIC	615.2320276	759.8987

Table-4: Metric value in Sample (Estimation) One-Step-Ahead Forecast

Forecast Accuracy		
Metric	**ARIMA**	**Exponential Smoothing**
N	71	72

RMSE	149522.3179	179558.3505
MAE	90708.50923	103233.6933
MAPE	0.108690456	0.116727669
MASE	0.049683086	0.05654341

Table-5: Projected value of population growth in Bangladesh for out-of-sample forecast accuracy evaluation

	ARIMA			**Exponential Smoothing**		
Period	**One-Step-Ahead Forecast**	**Lower 95.0% PI**	**Upper 95.0% PI**	**One-Step-Ahead Forecast**	**Lower 95.0% PI**	**Upper 95.0% PI**
2022	171341022.6	170927874	171754669.9	171302663.7	170778029.9	171828102.1
2023	173468236.3	172277006.7	174663570.1	173260210.7	172081611.1	174442832.7
2024	175700607.5	173690114.6	177722669.5	175228879.2	173247804.4	177221216.4
2025	178011983.2	175189534.2	180856986.8	177208669	174296124.2	180145347.5
2026	180383995	176778247.5	184026145.4	179199580.3	175239583.3	183203822
2027	182803734.1	178450994.3	187208921.8	181201613	176087520.2	186388910.5
2028	185262124.4	180199883	190394489.5	183214767	176847038.7	189695118
2029	187752782.9	182016735.5	193577816	185239042.5	177523778.8	193118413.4
2030	190271219.4	183894017.9	196757120.7	187274439.3	178122365	196655781.1
2031	192814275.4	185825147.4	199932423.3	189320957.6	178646686.1	200304941.2
2032	195379728.4	187804525.1	203104701.1	191378597.2	179100079.4	204064165.3
2033	197966014.9	189827455	206275396.3	193447358.3	179485457	207932150.1
2034	200572035	191890025.2	209446130.9	195527240.7	179805396	211907927.5
2035	203197014.7	193988984.2	212618545.2	197618244.6	180062204.3	215990798.4
2036	205840409.4	196121628	215794209.3	199720369.8	180257970.2	220180283.5
2037	208501836.2	198285702.8	218974579.8	201833616.5	180394600.2	224476085.2
2038	211181025.5	200479322.4	222160981.8	203957984.5	180473848.6	228878058
2039	213877787.7	202700901.4	225354606	206093473.9	180497341.3	233386184.9
2040	216591989.5	204949100.3	228556514.5	208240084.8	180466594.4	238000558.8
2041	219323537.1	207222781.1	231767650.2	210397817	180383029.2	242721367.1
2042	222072364.4	209520971.5	234988848.3	212566670.7	180247985.7	247548879
2043	224838425.2	211842836	238220847.5	214746645.7	180062732	252483435
2044	227621686.7	214187652.7	241464301.9	216937742.2	179828473.9	257525438.3
2045	230422126	216554794.5	244719791.1	219139960	179546362.1	262675347.2
2046	233239726.9	218943713.6	247987829.1	221353299.3	179217498	267933668.9
2047	236074478.2	221353929.1	251268873.4	223577759.9	178842939.8	273300954.4
2048	238926371.7	223785016.9	254563331.5	225813342	178423706.6	278777793.3
2049	241795402	226236600.9	257871567.7	228060045.4	177960782.8	284364810.3

2050	244681565	228708346.6	261193908.4	230317870.2	177455121.3	290062661.1
2051	247584857.9	231199955	264530646.8	232586816.5	176907646.7	295872030.3
2052	250505278.9	233711157.8	267882047.2	234866884.1	176319257.9	301793627.7
2053	253442826.5	236241713.5	271248348.3	237158073.2	175690830.5	307828186.6
2054	256397499.8	238791403.9	274629766.1	239460383.6	175023219	313976461.5
2055	259369298.1	241360031.3	278026497.1	241773815.4	174317258.6	320239226
2056	262358221	243947415.9	281438720.1	244098368.7	173573766.6	326617271.7
2057	265364268	246553393.9	284866598.1	246434043.3	172793544.4	333111406.2
2058	268387439	249177815.5	288310280.5	248780839.4	171977378.4	339722451.8
2059	271427733.8	251820543.5	291769904	251138756.8	171126041.3	346451244.9
2060	274485152.3	254481452	295245594.4	253507795.6	170240293.3	353298634.1
2061	277559694.3	257160425.1	298737467.4	255887955.9	169320883	360265479.6
2062	280651359.9	259857355.9	302245629.9	258279237.5	168368548.3	367352652.6
2063	283760149	262572145.6	305770180.4	260681640.5	167384017	374561033.9
2064	286886061.6	265304702.8	309311210.4	263095165	166368008.1	381891513.8
2065	290029097.6	268054942.7	312868804.5	265519810.8	165321231.7	389344990.7
2066	293189257	270822786.7	316443041.4	267955578	164244390.3	396922371.2
2067	296366539.9	273608161.6	320033994.3	270402466.7	163138178.8	404624569.3
2068	299560946.2	276410999	323641731.5	272860476.7	162003285.5	412452505.5
2069	302772475.9	279231235.6	327266316.3	275329608.1	160840392.2	420407107
2070	306001129	282068811.8	330907808.4	277809861	159650174.8	428489306.6

6. Conclusion

According to the findings, ARIMA and the exponential smoothing model are not only constant, but also the best method for predicting annual population growth in Bangladesh for the upcoming 23 years. According to these models, Bangladesh's total population will be approximately more than 306 million or 277 million by 2070.

This clearly demonstrates that, despite Bangladesh's current high levels of unemployment, crime, food shortages, and poverty, population growth will not pose a threat to the country's future. The slowing of population growth indicates that Bangladesh will be able to control its population. These results are consistent with those stated by every other national and international bureau. Such findings are critical for the government of Bangladesh along with other organizations, especially when it comes to making plans for the coming decades.

Data Availability

The data used in the present study is available from the following website the World Data Bank (https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=BD) and our world in data (https://ourworldindata.org/). However, the file generated for analysis by authors will be made available upon reasonable request.

Conflict of Interest

The author(s) declare no conflict of interest for the present study.

Funding Source

None.

Authors Contribution

Sofi Mahmud Parvez contributed in conception, data accessibility, data analysis and prepared the draft manuscript. Nur Hosain Md. Ariful Azim contributed in data analysis, literature review and revised the whole paper.

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Sofi Mahmud Parvez was born Cumilla, Bangladesh in 1997. He received B.Sc. (Hons) degree in Applied Mathematics from Noakhali Science and Technology University, Noakhali-Bangladesh in 2019. He achieved the MS degree in Applied Mathematics from the same University in 2020.

Currently, Sofi Mahmud Parvez is working as a lecturer in the department of Electrical and Electronic Engineering of Southeast University, Dhaka, Bangladesh. His research interest in Bio-Mathematics, especially mathematical modelling on epidemiology, ecology and demography.

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