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Where Is Eritrea Going In Terms Of Population Growth? Insights From The ARIMA Approach

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Abstract

Employing annual time series data on total population in Eritrea from 1960 to 2011, we model and forecast total population over the next 39 years using the Box – Jenkins ARIMA technique. Diagnostic tests such as the ADF tests show that Eritrea annual total population is I (2). Based on the AIC, the study presents the ARIMA (2, 2, 1) model as the best model. The diagnostic tests further indicate that the presented model is quite stable. The results of the study establishes that total population in Eritrea will gradually rise in the next 39 years and in 2050 Eritrea's total population will be approximately 7.6 million people. In order to take advantage of the expected increase in total population in Eritrea, 3 policy recommendations have been proposed.

Key Words: Eritrea, Forecasting, Population

JEL Codes: C53, Q56, R23

INTRODUCTION

Eritrea, shaped like a hatchet, lies north of the equator and just north of the Horn of Africa. It is bounded in the northwest by the Sudan, in the south by Ethiopia, and in the southeast by Djibouti. Its longest border, the "handle" of the hatchet, is in the east on the Red Sea (Government of Eritrea, 1997). Present day Eritrea is a colonial creation, basically, through the Eritrean People's Liberation Front (EPLF) which later on transformed into a fully fledged political party, the People's Front for Democracy and Justice (PFDJ), led by Isaias Afwerki, who became the country's first (and, to date, only) President in 1993 (Australian Government, 2017). Eritrea is a highly centralized, authoritarian regime under the control of President Isaias Afwerki. The People's Front for Democracy and Justice (PFDJ), headed by the president, is the sole political party. There have been no national level elections since the country's independence from Ethiopia in 1993 (United States Department of State, 2017).

As the 21st century began, the world's population was estimated to be almost 6.1 billion people (Tartiyus *et al*, 2015). Projections by the United Nations place the figure at more than 9.2 billion by the year 2050 before reaching a maximum of 11 billion by 2200. Over 90% of that population will inhabit the developing world (Todaro & Smith, 2006). The problem of population growth is basically not a problem of numbers but that of human welfare as it affects the provision of welfare and development. The consequences of rapidly growing population manifests heavily on species extinction, deforestation, desertification, climate change and the destruction of natural ecosystems on one hand; and unemployment, pressure on housing, transport traffic congestion, pollution and infrastructure security and stain on amenities (Dominic *et al*, 2016). No census has been carried out in Eritrea since 1938, and obtaining any statistical information on the country is difficult. Estimates of Eritrea's current population from credible international organisations range from 5.2 million persons (Country Meters) and 6.5 million persons (CIA World Factbook). The majority of Eritreans are young, with the median age estimated as being 19.3 years (Australian Government, 2017). In Eritrea, just like in any other part of the world, population forecasting is important for policy dialogue. This study endeavors to model and forecast population of Eritrea using the Box-Jenkins ARIMA technique.

REVIEW OF PREVIOUS STUDIES

In an Asian study, Zakria & Muhammad (2009) forecasted population using ARIMA models, and used a data set ranging from 1951 - 2007; and revealed that the ARIMA (1, 2, 0) model was the best model for forecasting total population in Pakistan. In another Asian study, Beg & Islam (2016) studied population growth of Bangladesh using an Autoregressive Time Trend (ATT) model based on a data set ranging over 1965 – 2003 and established that there will be a downward population growth for Bangladesh for the extended period up to 2043. In an African study, closer to Eritrea; Ayele & Zewdie (2017) analyzed human population size and its pattern in Ethiopia using ARIMA models and employing annual data from 1961 - 2009 and concluded that the most suitable model for modeling and forecasting population in Ethiopia was the ARIMA (2, 1, 2) model. In the case of Eritrea, the study will employ the Box-Jenkins ARIMA technique for the data set ranging from 1960 - 2017.

MATERIALS & METHODS

ARIMA Models

ARIMA models are often considered as delivering more accurate forecasts then econometric techniques (Song *et al*, 2003b). ARIMA models outperform multivariate models in forecasting performance (du Preez & Witt, 2003). Overall performance of ARIMA models is superior to that of the naïve models and smoothing techniques (Goh & Law, 2002). ARIMA models were developed by Box and Jenkins in the 1970s and their approach of identification, estimation and diagnostics is based on the principle of parsimony (Asteriou & Hall, 2007). The general form of the ARIMA (p, d, q) can be represented by a backward shift operator as:

$$\emptyset(B)(1-B)^d POP_t = \theta(B)\mu_t \ldots \ldots \ldots \ldots [1]$$

Where the autoregressive (AR) and moving average (MA) characteristic operators are:

$$\emptyset(B) = \left(1 - \emptyset_1 B - \emptyset_2 B^2 - \cdots - \emptyset_p B^p\right) \ldots \ldots \ldots \ldots [2]$$

$$\theta(B) = \left(1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q\right) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [3]$$

and

$$(1 - B)^d POP_t = \Delta^d POP_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [4]$$

Where $\emptyset$ is the parameter estimate of the autoregressive component, θ is the parameter estimate of the moving average component, Δ is the difference operator, d is the difference, B is the backshift operator and μ_t is the disturbance term.

The Box – Jenkins Methodology

The first step towards model selection is to difference the series in order to achieve stationarity. Once this process is over, the researcher will then examine the correlogram in order to decide on the appropriate orders of the AR and MA components. It is important to highlight the fact that this procedure (of choosing the AR and MA components) is biased towards the use of personal judgement because there are no clear – cut rules on how to decide on the appropriate AR and MA components. Therefore, experience plays a pivotal role in this regard. The next step is the estimation of the tentative model, after which diagnostic testing shall follow. Diagnostic checking is usually done by generating the set of residuals and testing whether they satisfy the characteristics of a white noise process. If not, there would be need for model re – specification and repetition of the same process; this time from the second stage. The process may go on and on until an appropriate model is identified (Nyoni, 2018).

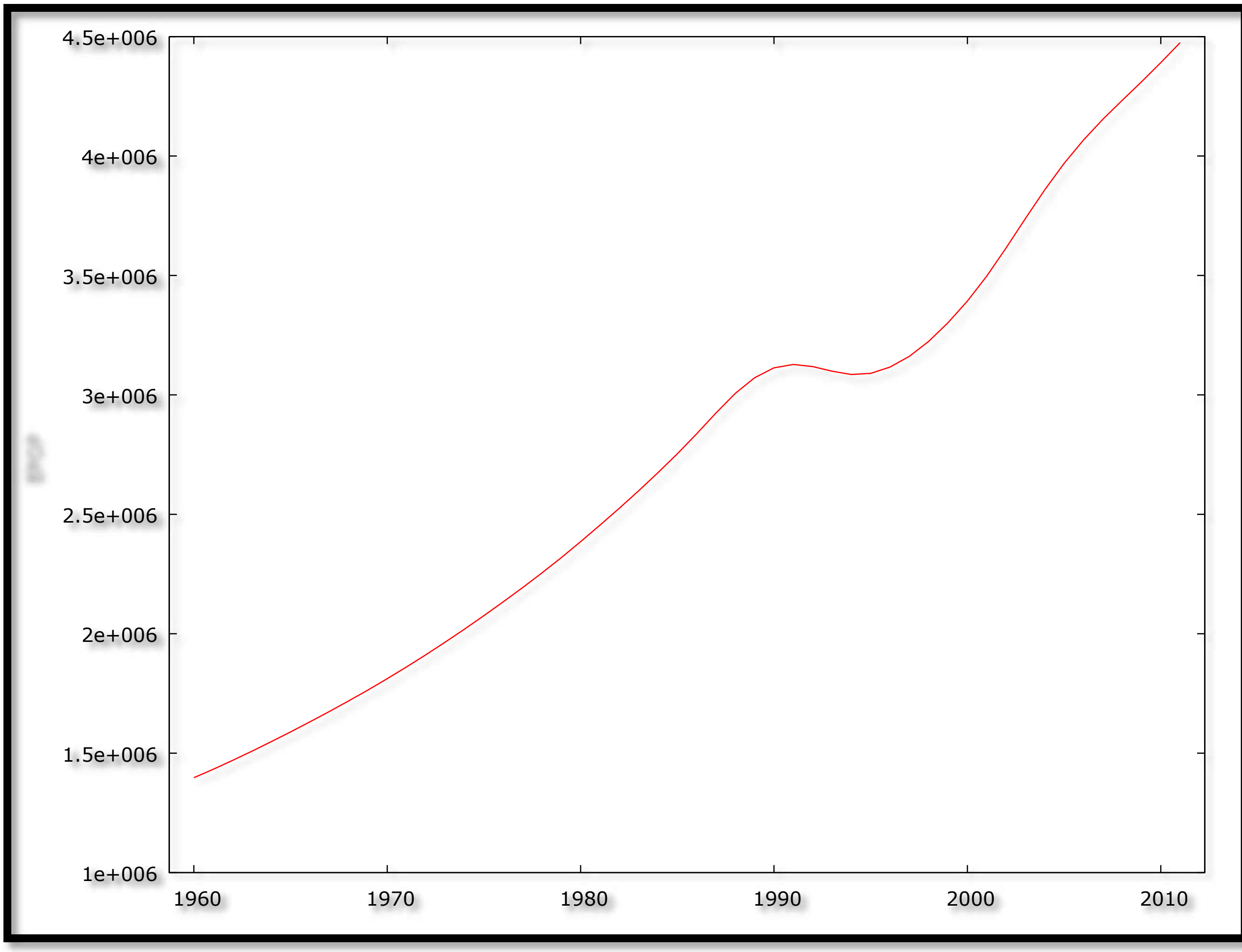
Data Collection

No census has been carried out in Eritrea since 1938, and obtaining any statistical information on the country is difficult (Australian Government, 2017). This study is based on 52 observations of annual total population in Eritrea (EPOP or simply POP), of which all the data was gathered from the World Bank online database (a well-known source of socio-economic data for, literally, all countries in the world).

Diagnostic Tests & Model Evaluation

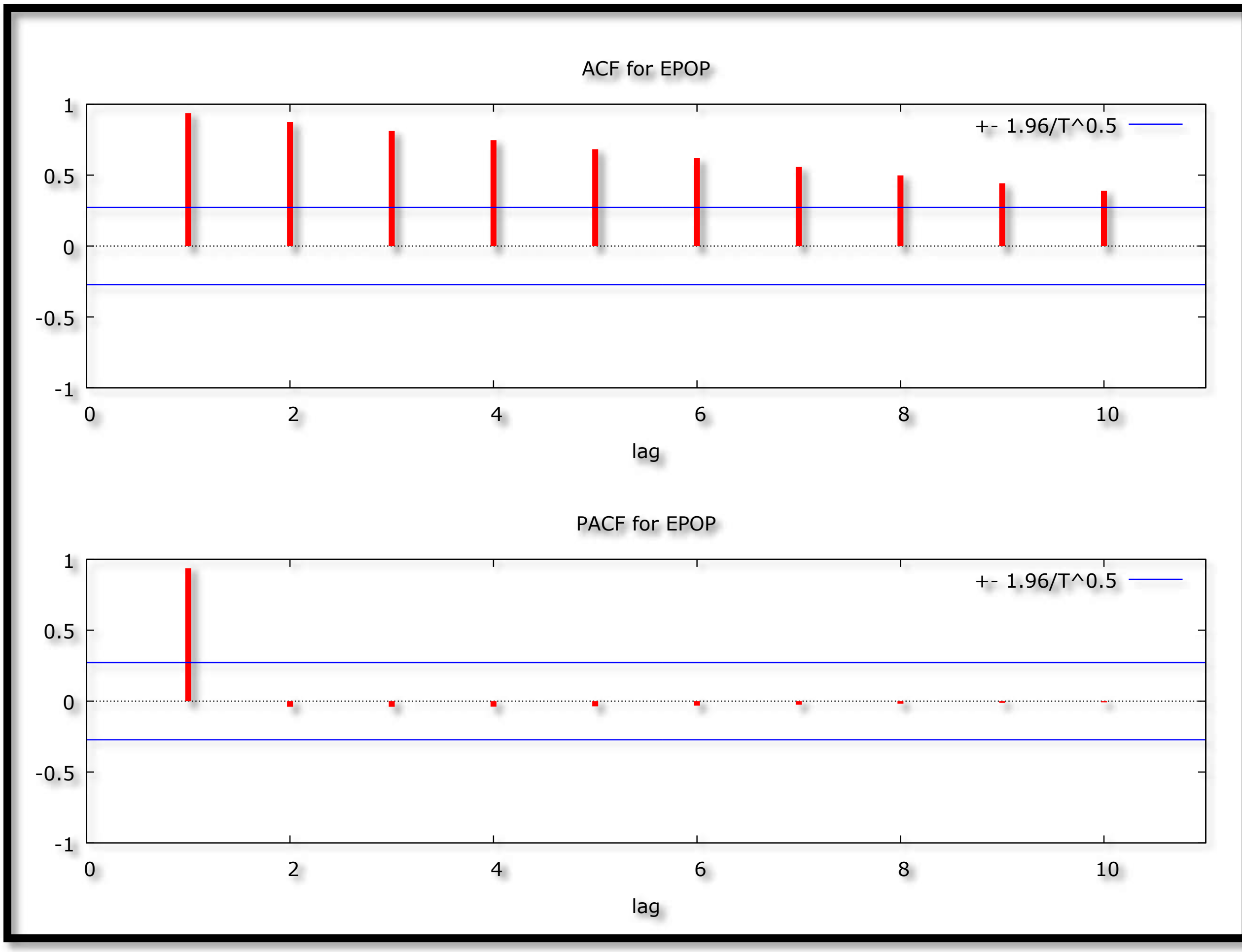
Stationarity Tests: Graphical Analysis

Figure 1



The Correlogram in Levels

Figure 2



The ADF Test

Table 1: Levels-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	1.531029	0.9992	-3.577723	@1%	Not stationary
			-2.925169	@5%	Not stationary
			-2.600658	@10%	Not stationary

Table 2: Levels-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-2.088508	0.5373	-4.186481	@1%	Not stationary
			-3.518090	@5%	Not stationary
			-3.189732	@10%	Not stationary

Table 3: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	3.021994	0.9991	-2.615093	@1%	Not stationary
			-1.947975	@5%	Not stationary
			-1.612408	@10%	Not stationary

Figures 1 and 2 show that the Eritrean POP series is not stationary and tables 1 – 3 confirm this.

The Correlogram (at 1st Differences)

Figure 3

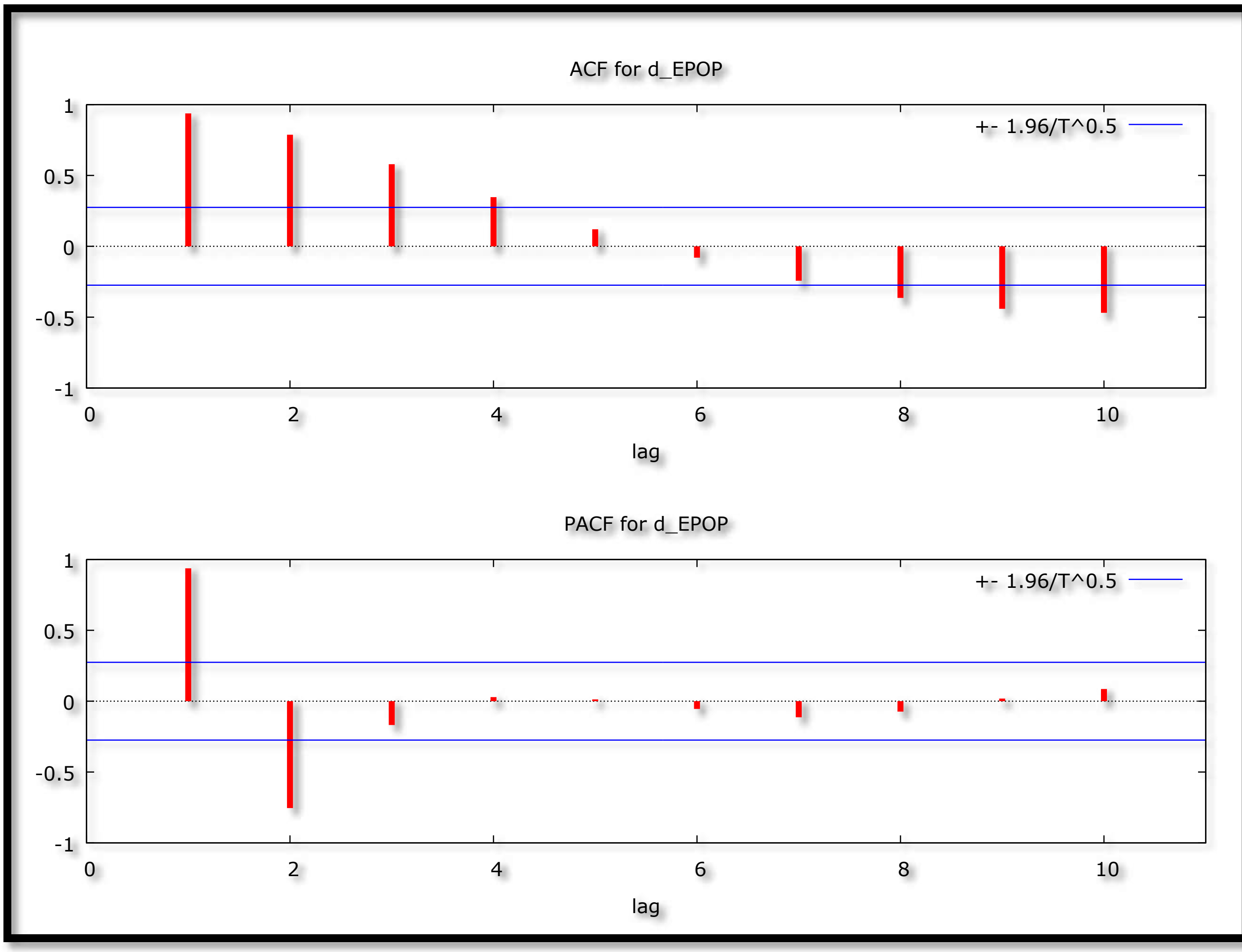


Table 4: 1st Difference-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-2.904799	0.0523	-3.577723	@1%	Not stationary
			-2.925169	@5%	Not stationary
			-2.600658	@10%	Stationary

Table 5: 1st Difference-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-3.301264	0.0807	-4.205004	@1%	Not stationary
			-3.526609	@5%	Not stationary
			-3.194611	@10%	Stationary

Table 6: 1st Difference-without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	0.833151	0.8875	-2.619851	@1%	Not stationary
			-1.948686	@5%	Not stationary
			-1.612036	@10%	Not stationary

Figure 3 and tables 4 – 6 also illustrate the Eritrean POP series is not stationary even after taking first differences.

The Correlogram in (2nd Differences)

Figure 4

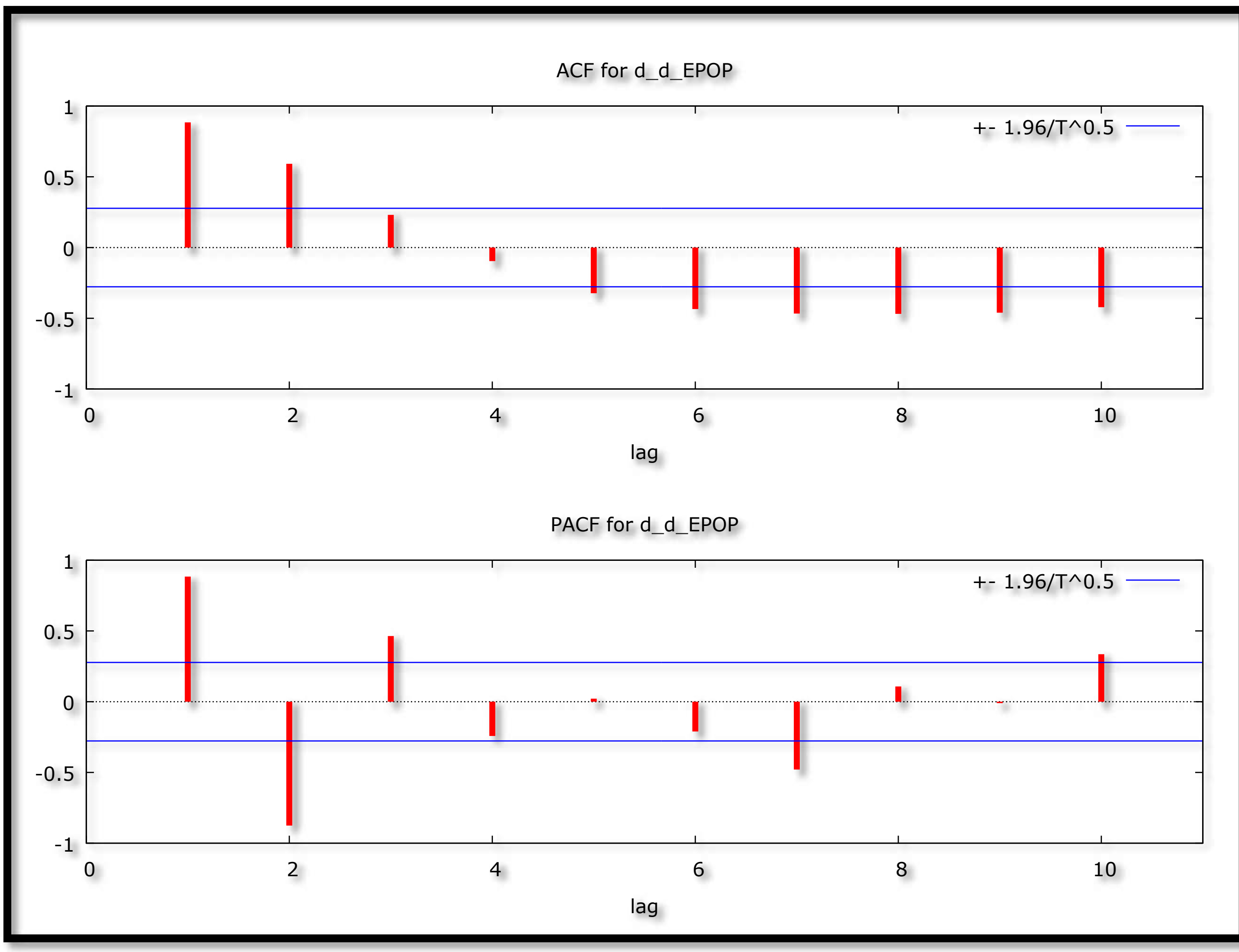


Table 7: 2nd Difference-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-4.509179	0.0008	-3.592462	@1%	Stationary
			-2.931404	@5%	Stationary
			-2.603944	@10%	Stationary

Table 8: 2nd Difference-trend & intercept

Variable	ADF Statistic	Probability	Critical Values	Conclusion

POP	-4.489384	0.0045	-4.186481	@1%	Stationary
			-3.518090	@5%	Stationary
			-3.189732	@10%	Stationary

Table 9: 2nd Difference-without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-4.374485	0.0001	-2.619851	@1%	Stationary
			-1.948686	@5%	Stationary
			-1.612036	@10%	Stationary

Figure 4 and tables 7 – 9 demonstrate that the Eritrea POP series is stationary at second differences and thus it is an I (2) variable.

Evaluation of ARIMA models (without a constant)

Table 10

Model	AIC	U	ME	MAE	RMSE	MAPE
ARIMA (1, 2, 1)	950.1973	0.037759	129.69	1876.2	2959.3	0.060277
ARIMA (1, 2, 0)	993.0483	0.059869	183.38	2772.8	4714.8	0.087379
ARIMA (0, 2, 1)	1009.139	0.070514	523.64	3747.9	5492.3	0.1231
ARIMA (2, 2, 1)	**911.5089**	0.025027	167.42	1308.5	1946.8	0.043622
ARIMA (3, 2, 1)	912.0199	0.024573	135.49	1292.2	1914.6	0.042789
ARIMA (4, 2, 1)	913.7115	0.024498	149.55	1294.4	1908.2	0.042955
ARIMA (5, 2, 1)	915.7062	0.024496	147.82	1293.8	1908.1	0.042924
ARIMA (2, 2, 0)	923.6995	0.029018	240.31	1554.1	2260.3	0.051744
ARIMA (4, 2, 0)	911.95	0.024548	158.25	1303.6	1913.2	0.043283
ARIMA (5, 2, 0)	913.8569	0.024524	149.76	1298.3	1911.2	0.043073
ARIMA (3, 2, 0)	912.8821	0.025257	115.06	1314.6	1973.5	0.043406

A model with a lower AIC value is better than the one with a higher AIC value (Nyoni, 2018). Theil's U must lie between 0 and 1, of which the closer it is to 0, the better the forecast method (Nyoni, 2018). The study will consider the AIC in order to choose the best model. Thus, the ARIMA (2, 2, 1) model is selected for forecasting total population in Eritrea.

Residual & Stability Tests

ADF Tests of the Residuals of the ARIMA (2, 2, 1) Model

Table 11: Levels-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
W_t	-4.285632	0.0017	-3.615588	@1%	Stationary
			-2.941145	@5%	Stationary
			-2.609066	@10%	Stationary

Table 12: Levels-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
W_t	-4.419224	0.006	-4.219126	@1%	Stationary
			-3.533083	@5%	Stationary

			-3.198312	@10%	Stationary

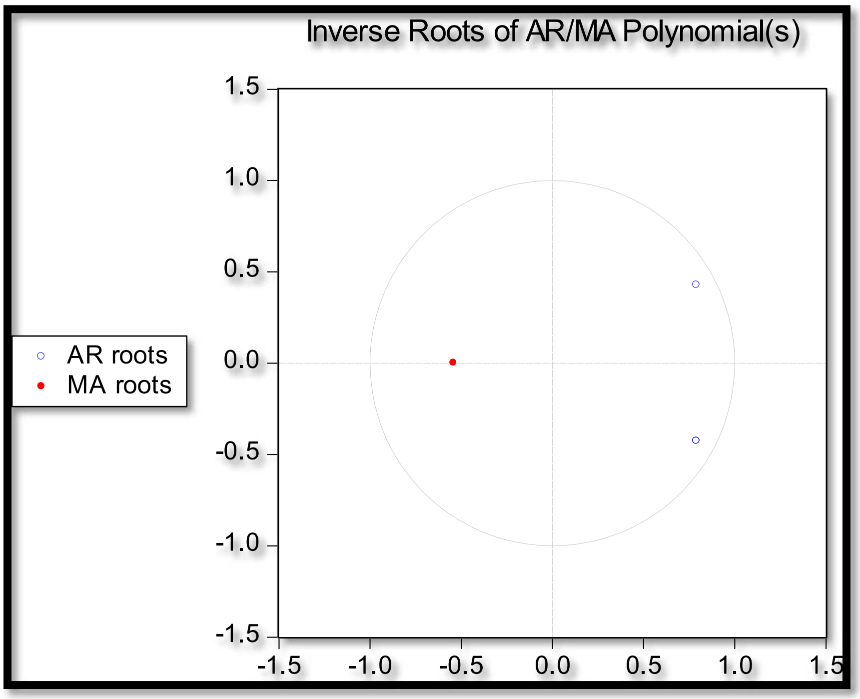
Table 13: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
W_t	-4.052361	0.0002	-2.627238	@1%	Stationary
			-1.949856	@5%	Stationary
			-1.611469	@10%	Stationary

As shown above, in tables 11 – 13; the residuals of the ARIMA (2, 2, 1) model are stationary.

Stability Test of the ARIMA (2, 2, 1) Model

Figure 5



Since the corresponding inverse roots of the characteristic polynomial lie in the unit circle, it illustrates that the selected ARIMA (2, 2, 1) model is quite stable.

RESULTS

Descriptive Statistics

Table 14

Description	Statistic
Mean	2743200
Median	2795100
Minimum	1397500
Maximum	4474700
Standard deviation	892130

Skewness	0.22026
Excess kurtosis	-0.99927

As shown above, the mean is positive, i.e. 2743200. The wide gap between the minimum (i.e 1397500) and the maximum (i.e. 4474700) is consistent with the reality that the Eritrea POP series is gradually trending upwards. The skewness is 0.22026 and the most critical characteristic is that it is positive, indicating that the Eritrea POP series is positively skewed and non-symmetric. Excess kurtosis is -0.99927; showing that the POP series is not normally distributed.

Results Presentation[1]

Table 15

ARIMA (2, 2, 1) Model:

$$\Delta^2 POP_{t-1} = 1.55604\Delta^2 POP_{t-1} - 0.782127\Delta^2 POP_{t-2} + 0.534171\mu_{t-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

P: (0.0000) (0.0000) (0.0000)

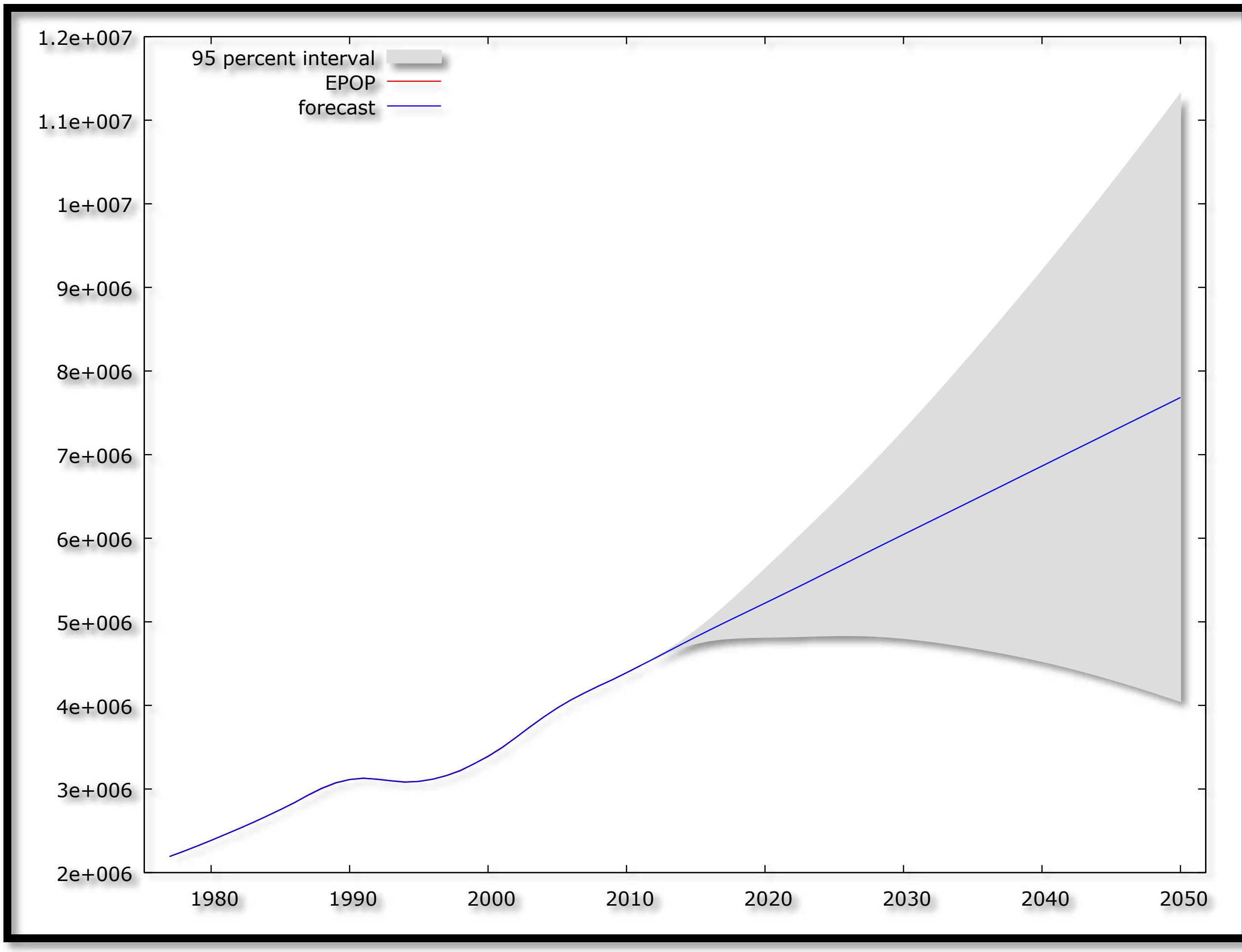
S. E: (0.0896177) (0.0890864) (0.132243)

Variable	Coefficient	Standard Error	z	p-value
AR (1)	1.55604	0.0896177	17.36	0.0000***
AR (2)	-0.782127	0.0890864	-8.779	0.0000***
MA (1)	0.534171	0.132243	4.039	0.0000***

Forecast Graph

Figure 6

[1] *The *, ** and *** means significant at 10%, 5% and 1% levels of significance; respectively.*



Predicted Total Population

Table 16

Year	Actual	Prediction	Std. Error	95% Confidence Interval
2000	3392801.00	3389435.96		
2001	3497124.00	3492721.34		
2002	3614639.00	3615473.72		
2003	3738265.00	3741453.73		
2004	3858623.00	3859378.79		
2005	3969007.00	3968712.57		
2006	4066648.00	4066584.36		
2007	4153332.00	4152295.35		

2008	4232636.00	4233486.89		
2009	4310334.00	4308571.69		
2010	4390840.00	4392246.48		
2011	4474690.00	4476220.15		
2012		4560729.81	1929.664	4556947.74 - 4564511.89
2013		4647561.63	8125.193	4631636.54 - 4663486.71
2014		4733913.10	20318.035	4694090.49 - 4773735.72
2015		4818897.72	39278.729	4741912.83 - 4895882.62
2016		4902131.14	64779.635	4775165.39 - 5029096.89
2017		4983708.67	95813.596	4795917.48 - 5171499.87
2018		5064079.27	130944.138	4807433.47 - 5320725.06
2019		5143866.92	168671.296	4813277.25 - 5474456.58
2020		5223691.47	207724.582	4816558.77 - 5630824.17
2021		5304029.38	247236.026	4819455.68 - 5788603.09
2022		5385137.24	286788.307	4823042.48 - 5947231.99
2023		5467041.64	326363.989	4827379.97 - 6106703.30
2024		5549583.30	366235.453	4831775.00 - 6267391.59
2025		5632493.56	406833.162	4835115.21 - 6429871.91
2026		5715478.97	448619.871	4836200.18 - 6594757.75
2027		5798293.00	491988.556	4834013.15 - 6762572.85
2028		5880781.60	537195.156	4827898.44 - 6933664.76
2029		5962897.85	584331.753	4817628.66 - 7108167.04
2030		6044689.25	633338.878	4803367.85 - 7286010.64
2031		6126266.37	684047.621	4785557.67 - 7466975.07
2032		6207764.16	736236.369	4764767.40 - 7650760.93
2033		6289306.10	789685.991	4741550.00 - 7837062.20
2034		6370978.78	844221.124	4716335.78 - 8025621.78

2035	6452820.37	899731.641	4689378.75 - 8216261.98
2036	6534822.52	956174.627	4660754.69 - 8408890.35
2037	6616942.42	1013561.565	4630398.26 - 8603486.59
2038	6699119.96	1071937.340	4598161.38 - 8800078.54
2039	6781295.08	1131357.617	4563874.90 - 8998715.26
2040	6863421.37	1191869.754	4527399.57 - 9199443.16
2041	6945473.55	1253500.390	4488657.94 - 9402289.17
2042	7027448.64	1316250.746	4447644.58 - 9607252.69
2043	7109361.69	1380098.796	4404417.76 - 9814305.63
2044	7191238.55	1445006.212	4359078.41 - 10023398.68
2045	7273107.57	1510927.415	4311744.25 - 10234470.89
2046	7354992.73	1577818.210	4262525.87 - 10447459.60
2047	7436909.13	1645642.184	4211509.72 - 10662308.54
2048	7518861.51	1714373.959	4158750.29 - 10878972.72
2049	7600845.44	1783999.331	4104271.00 - 11097419.87
2050	7682850.33	1854513.007	4048071.63 - 11317629.03

Figure 6 (with a forecast range from 2011 – 2050) and table 16, clearly show that Eritrea population is indeed set to continue rising gradually, in the next 39 years. With a 95% confidence interval of 4048072 to 11317629 and a projected total population of 7682850 by 2050, the chosen ARIMA (2, 2, 1) model is consistent with the population projections by the UN (2015) which forecasted that Eritrea's population will be approximately 10421000 by 2050. Our results are also consistent with the UN (2017) which forecasted that Eritrea's population will be approximately 9607000 by 2050. This high level of consistency shows that our model is indeed suitable for forecasting total population in Eritrea over the study period.

Eritrea has considerable economic potential. It is located on the busy and strategic Red Sea shipping lane; has mineral resources and considerable tourism potential; and a young and well-educated population (Australian Government, 2017). Therefore, the projected increase in total population in Eritrea is avenue for growth given Eretria's human and natural resource endowments. Hence, the government of Eritrea must take advantage of that and act now.

Policy Implications

1. The government of Eritrea should start investing more in infrastructural development, for example, schools, universities, colleges, hospitals and clinics; in order to cater for the expected increase in total population.

2. The projected increase in total population in Eritrea justifies the need for more businesses to provide for the expected increase in demand for various commodities.
3. There is need to improve health service delivery in Eritrea in order to ensure a healthier society, especially in light of such a likely increase in total population.

CONCLUSION

The paper applied the ARIMA approach in order to study population dynamics in Eritrea. The main objective of the study was to model and forecast total population in Eritrea. The ARIMA (2, 2, 1) model is the most parsimonious model to forecast the population of Eritrea for the next 39 years. The model predicts that by 2050, Eritrea's population would be approximately, 7.6 million people. These findings are essential for the government of Eritrea, especially, in terms of planning for the future.

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