Modeling and forecasting population in Bangladesh: a Box-Jenkins ARIMA approach

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MODELING AND FORECASTING POPULATION IN BANGLADESH: A BOX – JENKINS ARIMA APPROACH

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Abstract

Employing annual time series data on total population in Bangladesh from 1960 to 2017, I model and forecast total population over the next 3 decades using the Box – Jenkins ARIMA technique. Diagnostic tests such as the ADF tests show that Bangladesh annual total population is neither I (1) nor I (2) but for simplicity purposes, the researcher has assumed it is I (2). Based on the AIC, the study presents the ARIMA (4, 2, 1) model. The diagnostic tests further indicate that the presented model is very stable and quite reliable. The results of the study reveal that total population in Bangladesh will continue to sharply rise in the next three decades. In order to deal with the threats posed by a large population, 3 policy recommendations have been suggested.

Key Words: Population, Forecasting, Bangladesh

JEL Codes: C53, Q56, R23

INTRODUCTION

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). Population problem is one of the main problems in Bangladesh at the current time (Haque *et al*, 2012). The fast growth of population during the past decades has frustrated the development efforts in Bangladesh (Sultana *et al*, 2015). Bangladesh is an over populated country and the growth in resources has not been keeping pace with the growth in population (Haque *et al*, 2012). 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

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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). In Bangladesh, just like in any other part of the world, population modeling and forecasting is important for policy dialogue, especially with regards to the future threat to natural resources, persistant unemployment and worsening poverty levels. This study endeavors to model and forecast population of Bangladesh using the Box-Jenkins ARIMA technique.

LITERATURE REVIEW

Theoretical Literature Review

The Malthus' population theory avers that population growth is harmful to economic growth and development in the sense that human population grows geometrically while the means of subsistance grows arithmetically being subject to the law of diminishing returns. Malthus concluded that population growth is a real problem to any economy. The Malthusian population prophecy is quite relevant in the case of Bangladesh, where unemployment and poverty continue to characterize Bangladesh in the face of continuous sharp population growth. Solow (1956), in support of Malthus (1798); argued that population growth is indeed a problem but he did not agree on the transmission mechanism of this problem. How population growth would be a real problem for the economy – that's where Solow and Malthus failed to speak with one voice. Solow used the term "population growth rate" while Malthus preferred the term "population level". Solow (1956) argued that an increase in the "population growth rate" would reduce the capital per worker as well as the steady-state output per worker and concluded that higher population growth could retard productivity and economic growth. However, Ahlburg (1998) and Becker *et al* (1999) did not agree with both Solow (1956) and Malthus (1798) but rather proposed that population growth is not a problem at all but actually an avenue for economic growth. Ahlburg (1998) opined that an increase in population growth would lead to an increase the need for goods and services through the "technology-pushed" and the "demand-pulled" channels while Becker *et al* (1999) reiterated that high population growth rate induces high labour force which is the source of real wealth.

Empirical Literature Review

Zakria & Muhammad (2009), in the case of Pakistan; forecasted population using Box-Jenkins ARIMA models, and relied on a data set ranging from 1951 to 2007; and found out that the ARIMA (1, 2, 0) model was the optimal model. Haque *et al* (2012) analyzed Bangladesh population projections using the logistic population model with a data set ranging from 1991 to 2006 and found out that the logistic population model has the best fit for population growth in Bangladesh. Beg & Islam (2016) modeled and forecasted population growth of Bangladesh using an autoregressive time trend model based on a data set ranging over 1965 – 2003 and uncovered a downward population growth for Bangladesh for the extended period up to 2043. Ayele & Zewdie (2017) analyzed human population size and its pattern in Ethiopia using Box-Jenkins ARIMA models and employing annual data from 1961 to 2009 and found out that the best model for modeling and forecasting population in Ethiopia was the ARIMA (2, 1, 2) model. In the case of Bangladesh, I will employ the Box-Jenkins ARIMA methodology for the data set ranging from 1960 to 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 forecasting equation for total population with ARIMA (p, d, q) models, where the p denotes the order of the autoregressive part, the d the order of integration and the q the order of the moving average part of the model, can be given, in terms of the lag operator notation as:

$$\emptyset_p(L)\Delta^d POP_t = \theta_q(L)\mu_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots[1]$$

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, 2018i).

Data Collection

This research is based on 58 observations of annual total population in Bangladesh, from 1960 – 2017. All the data was taken from the World Bank.

Diagnostic Tests & Model Evaluation

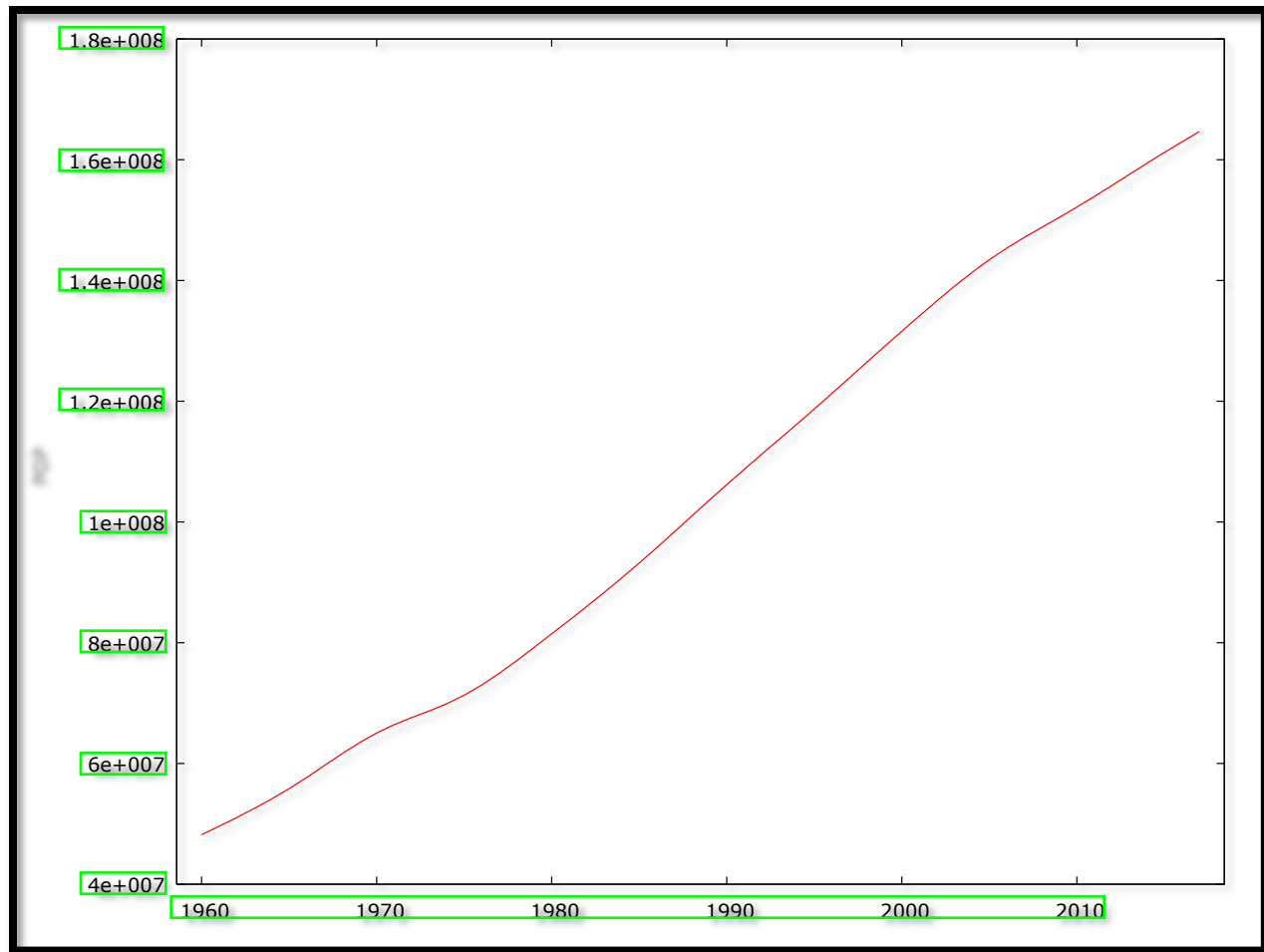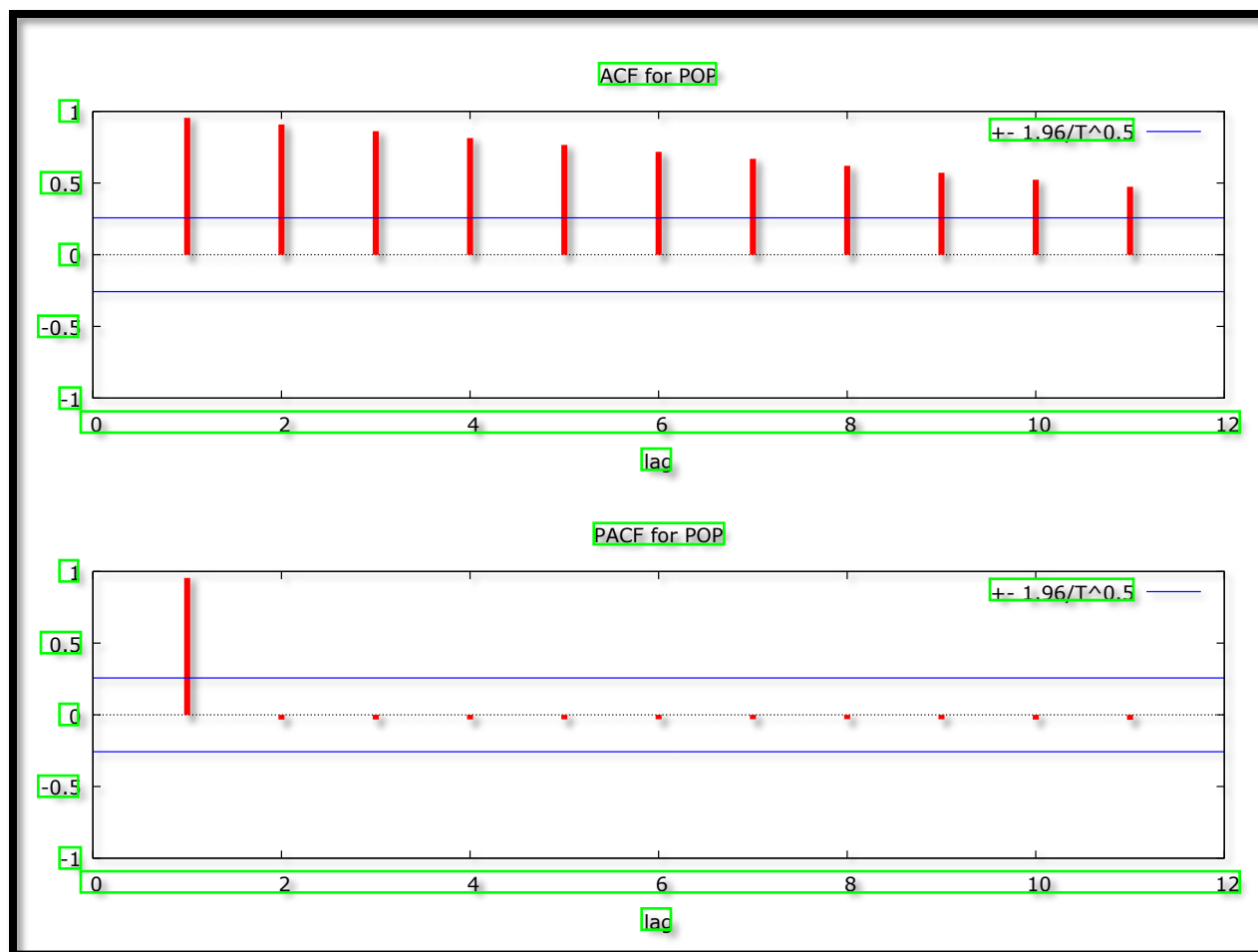## Stationarity Tests: Graphical Analysis

Figure 1

Figure 1 above indicates that the POP variable is not stationary since it is trending upwards over the period 1960 – 2017. This implies that the mean and varience of POP is changing over time.

The Correlogram in Levels

Figure 2

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ACF for POP

PACF for POP

The ADF Test

Table 1: Levels-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-1.472889	0.5387	-3.574446	@1%	Not stationary
			-2.923780	@5%	Not stationary
			-2.599925	@10%	Not stationary

Table 2: Levels-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-4.773851	0.0018	-4.156734	@1%	Stationary
			-3.504330	@5%	Stationary
			-3.181826	@10%	Stationary

Table 3: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-0.834628	0.3492	-2.614029	@1%	Not stationary
			-1.947816	@5%	Not stationary
			-1.612492	@10%	Not stationary

The Correlogram (at 1st Differences)

Figure 3
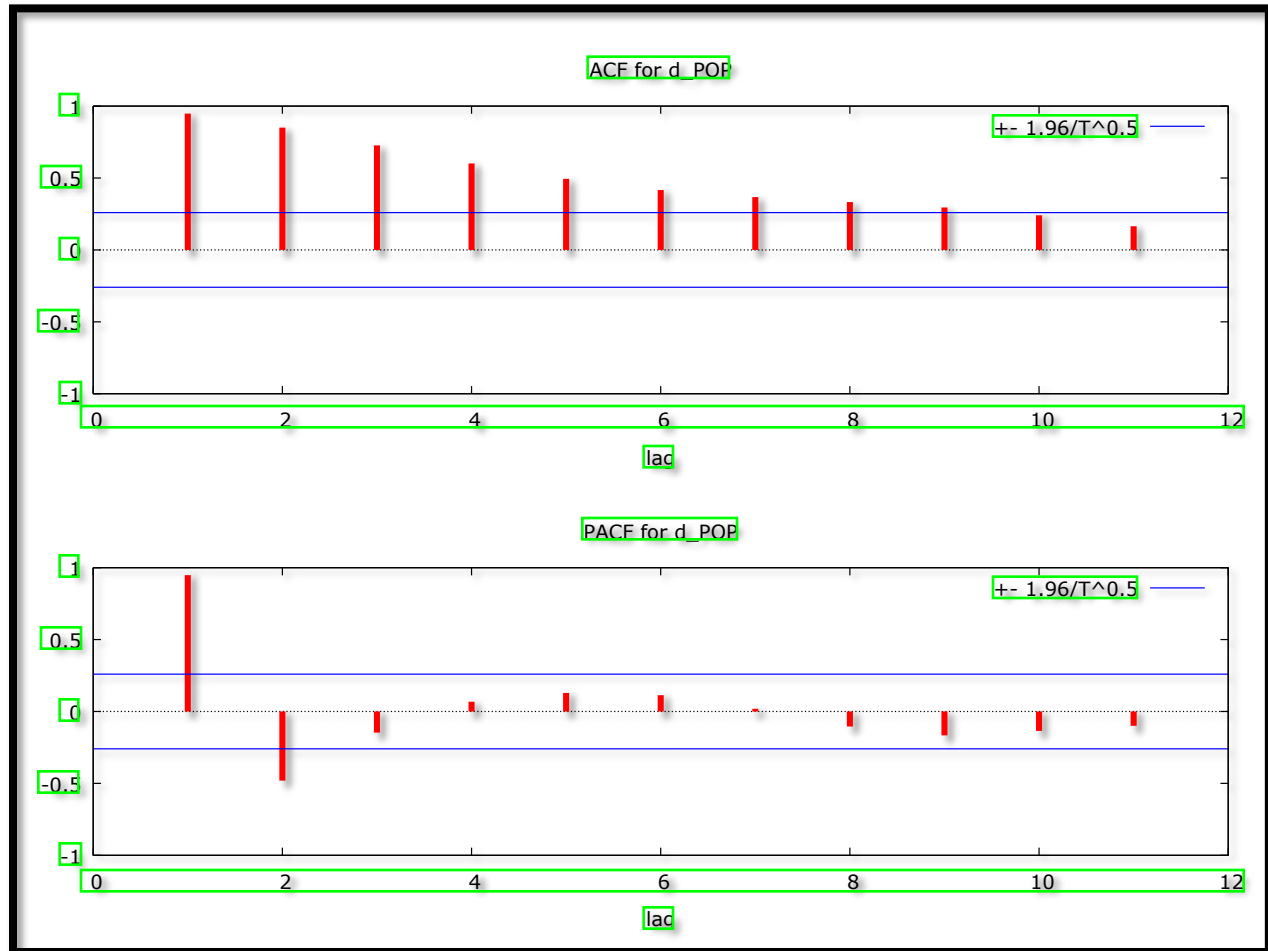
Table 4: 1st Difference-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-4.363501	0.0011	-3.581152	@1%	Stationary
			-2.926622	@5%	Stationary
			-2.601424	@10%	Stationary

Table 5: 1st Difference-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-0.271460	0.9894	-4.156734	@1%	Not stationary
			-3.504330	@5%	Not stationary
			-3.181826	@10%	Not stationary

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

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Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-0.023250	0.6700	-2.614029	@1%	Not stationary
			-1.947816	@5%	Not stationary
			-1.612492	@10%	Not stationary

Figures above, i.e. 2 and 3 as well as tables above, i.e. 1 – 6 indicate that the POP series is not stationary at both levels and in first differences.

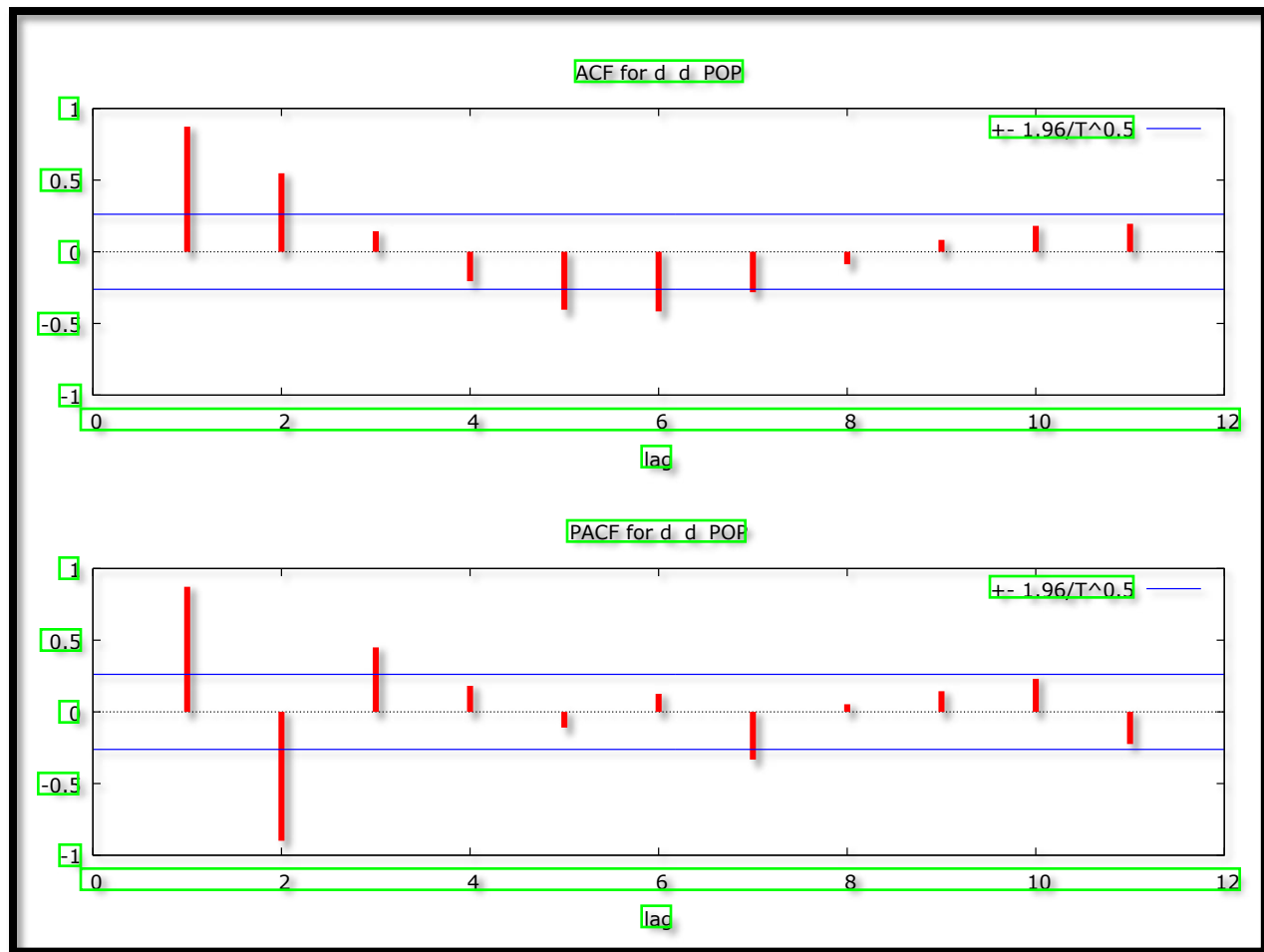## The Correlogram in (2nd Differences)

Figure 4

Table 7: 2nd Difference-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-1.592620	0.4780	-3.584349	@1%	Not stationary
			-2.928142	@5%	Not stationary
			-2.602225	@10%	Not stationary

Table 8: 2nd Difference-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-3.111448	0.1161	-4.175640	@1%	Not stationary
			-3.513075	@5%	Not stationary
			-3.186854	@10%	Not stationary

<div align="center">Table 9: 2nd Difference-without intercept and trend & intercept</div>

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

Variable	ADF Statistic	Probability	Critical Values		Conclusion
POP	-1.622736	0.0980	-2.617364	@1%	Not stationary
			-1.948313	@5%	Not stationary
			-1.612229	@10%	Stationary

Figure 4 above indicates that most of the autocorrelation coefficients are now closer to zero which is a feature of a stationary series. While tables 7 and 8 show that the POP variable is not yet stationary, table 9 indicates that the POP series is only stationary at 10% level of significance. Non-stationary at 2nd differences points to the fact that the POP series is sharply trending upwards. We could difference the series for the 3rd time but however, for the sake of simplicity, the researcher will however, assume that the POP series is an I (2) variable.

Evaluation of ARIMA models

<div align="center">Table 10</div>

Evaluation of ARIMA models (with a constant)						
Model	AIC	U	ME	MAE	RMSE	MAPE
ARIMA (0, 0, 1)	2116.938	10.652	-0.0000376	0	0	20.289
ARIMA (0, 1, 1)	1577.892	0.12569	-2393.4	0.0000209	0.0000241	0.23999
ARIMA (0, 1, 0)	1647.995	0.24004	0	0.0000396	0.0000443	0.44509
ARIMA (0, 2, 0)	1459.113	0.063215	0	79965	0.0000106	0.094804
Evaluation of ARIMA models (without a constant)						
ARIMA (0, 2, 1)	1395.057	0.036326	3450.9	45374	60017	0.054789
ARIMA (1, 2, 0)	1379.387	0.031751	294.73	37279	51741	0.044874
ARIMA (2, 2, 0)	1287.544	0.013124	2270.1	17227	22626	0.020926
ARIMA (3, 2, 0)	1271.406	0.011663	1615.9	14984	19493	0.018742
ARIMA (4, 2, 0)	1272.877	0.011614	1539.9	14764	19410	0.018505
ARIMA (4, 2, 1)	**1267.442**	**0.010937**	1484.2	14017	18424	0.017414

A model with a lower AIC value is better than the one with a higher AIC value (Nyoni, 2018n). Theil's U must lie between 0 and 1, of which the closer it is to 0, the better the forecast method (Nyoni, 2018l). In this research, the researcher will rely only on the AIC and Theil's U in order

to select the optimal model in terms of parsimony (AIC) and forecast accuracy (Theil's U). Therefore, the ARIMA (4, 2, 1) model is chosen.

Residual & Stability Tests

ADF Tests of the Residuals of the ARIMA (4, 2, 1) Model

Table 11: Levels-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ε_t	-2.894582	0.0545	-3.596616	@1%	Not stationary
			-2.933158	@5%	Not stationary
			-2.604867	@10%	Stationary

Table 12: Levels-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ε_t	-3.531040	0.0489	-4.192337	@1%	Not stationary
			-3.520787	@5%	Stationary
			-3.191277	@10%	Stationary

Table 13: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ε_t	-2.965375	0.0040	-2.621185	@1%	Stationary
			-1.948886	@5%	Stationary
			-1.611932	@10%	Stationary

Tables 11, 12 and 13 indicate that the residuals of the ARIMA (4, 2, 1) model are basically stationary.

Stability Test of the ARIMA (4, 2, 1) Model
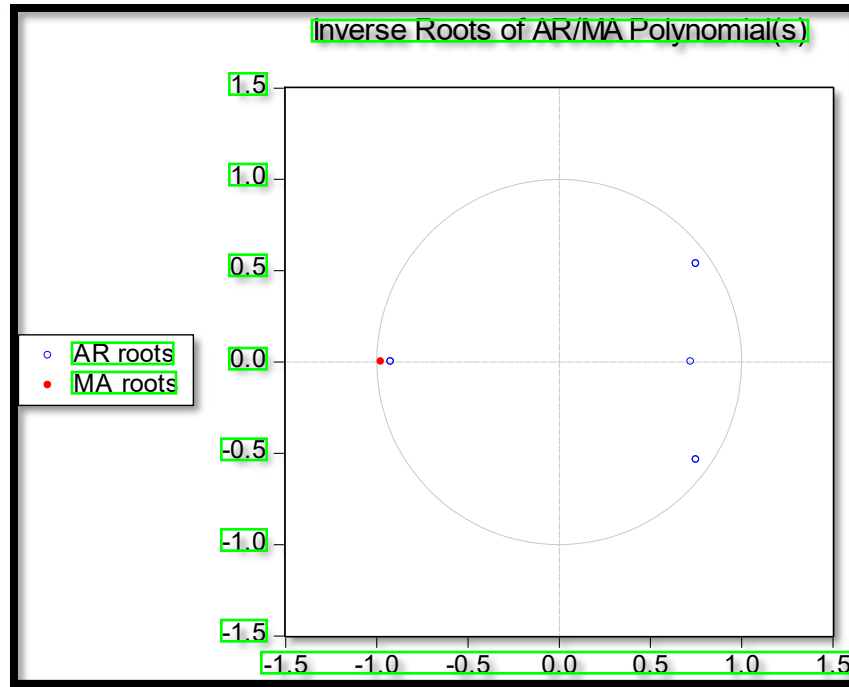
Figure 5

Figure 5 above indicates that the ARIMA (4, 2, 1) model, is quite stable, since the corresponding inverse roots of the characteristic polynomial lies in the unit circle.

RESULTS & DISCUSSION

Descriptive Statistics

Table 14

Description	Statistic
Mean	104300000
Median	102290000
Minimum	48200000
Maximum	164670000
Standard deviation	36878000
Skewness	0.099540
Excess kurtosis	-1.3647

As shown above in table 14, the mean is positive, i.e. 104300000. The wide gap between the minimum and the maximum is consistent with the reality that the POP series is sharply trending upwards. The skewness is 0.09954 and the most striking characteristic is that it is positive, indicating that the POP series is positively skewed and non-symmetric. Nyoni & Bonga (2017h) reiterate that the rule of thumb for kurtosis is that it should be around 3 for normally distributed variables but in this research, our kurtosis is -1.3647; showing that the POP series is not normally distributed.

Results Presentation[1]

ARIMA (4, 2, 1) Model:					
$\Delta^2 POP_{t-1} = 1.257\Delta^2 POP_{t-1} + 0.24\Delta^2 POP_{t-2} - 1.279\Delta^2 POP_{t-3} + 0.609\Delta^2 POP_{t-4} + 0.875\mu_{t-1} \ldots\ldots[2]$					
P:	(0.0000)	(0.0366)	(0.0000)	(0.0000)	(0.0000)
S. E:	(0.1123)	(0.1150)	(0.0967)	(0.1031)	(0.0952)

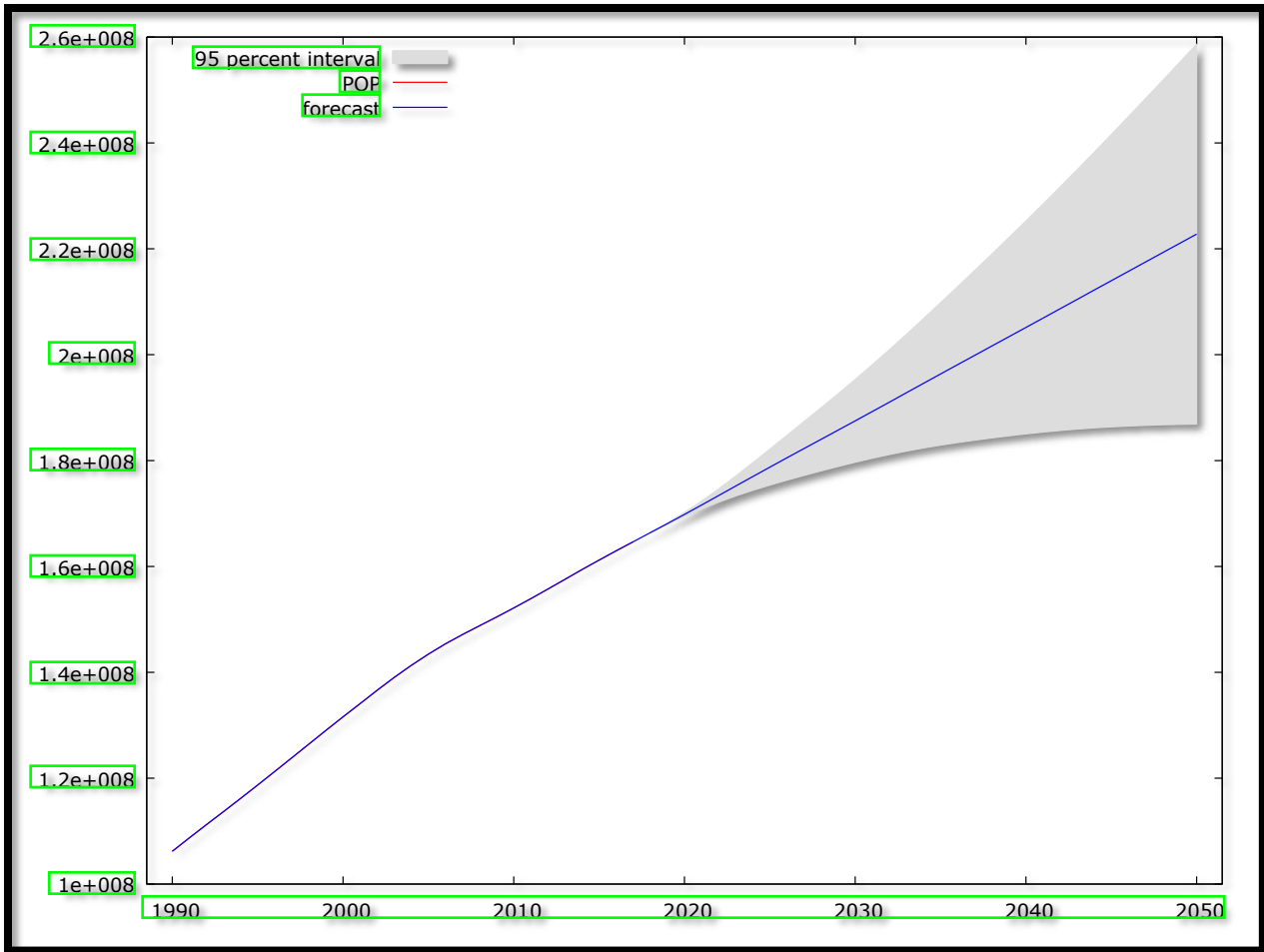| Variable	Coefficient	Standard Error	z		p-value
AR (1)	1.25697	0.112291	11.19		0.0000***
AR (2)	0.240326	0.114954	2.091		0.0366**
AR (3)	-1.27882	0.0966986	-13.22		0.0000***
AR (4)	0.609127	0.103109	5.908		0.0000***
MA (1)	0.874603	0.0951558	9.191		0.0000***

Interpretation of Results

Coefficients of the AR (1), AR (3) and AR (4) components are statistically significant at 1% level of significance while the coefficient of the AR (2) component is positive and statistically significant at 5% level of significance. AR terms take the lion's share in this model, implying that previous population levels are quite relevant in explaining future total annual population of Bangladesh. The MA component (i.e the coefficient 0.874603) is positive and statistically significant at 1% level of significance and this implies that previous disturbances (shocks) to Bangladesh population yield a positive impact on total population in the country.
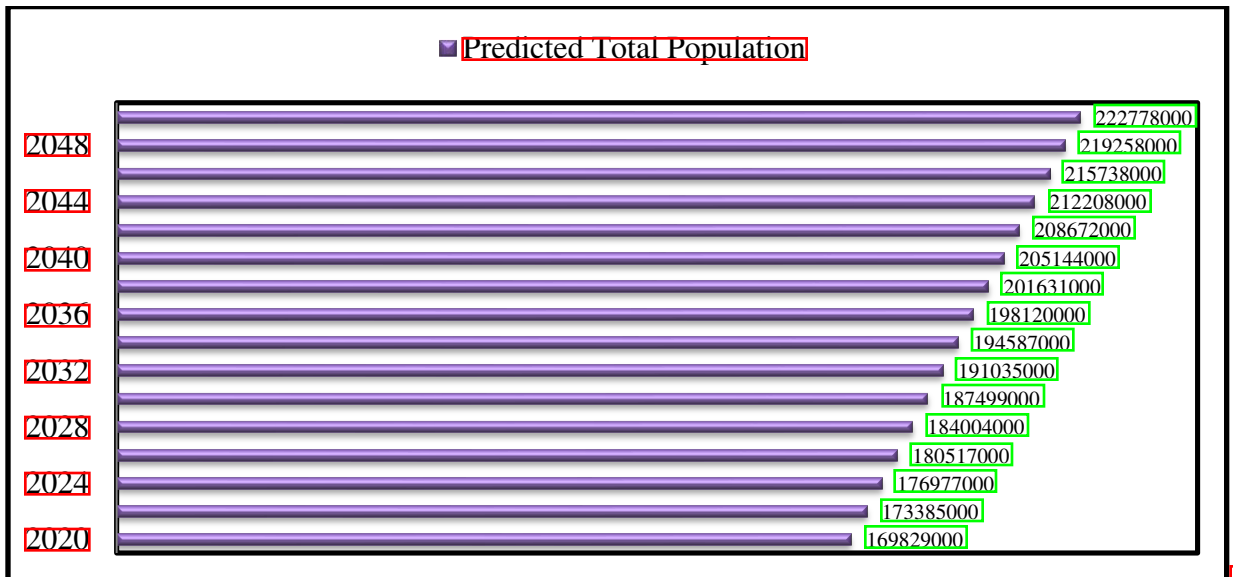
Forecast Graph

Figure 6

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

Predicted Total Population (for selected years)

Figure 7

Predicted Total Population

Year	Population
2048	222778000
	219258000
	215738000
2044	212208000
	208672000
2040	205144000
	201631000
2036	198120000
	194587000
2032	191035000
	187499000
2028	184004000
	180517000
2024	176977000
	173385000
2020	169829000

Figures 6 (with a forecast range of 32 years, i.e.; 2018 – 2050) and 7, clearly indicate that Bangladesh population is indeed set to continue rising sharply, at least for the next 3 decades; unless and until stern population control measures are put in place. With a 95% confidence interval of 186 890 000 to 258 666 000 and a projected total population of 222 778 000 by 2050, our model is consistent with the population projections by both the Population Reference Bureau (2016) and the UN (2015) which forecasted that Bangladesh's population will be approximately 202 million by 2050.

POLICY IMPLICATIONS

i. There is need to put in place and enforce family planning policies and practices in Bangladesh.
ii. The government of Bangladesh should promote the smaller family size norm.
iii. Sex education must be delivered in order to control fertility in Bangladesh.

CONCLUSION

The ARIMA (4, 2, 1) model is an appropriate and most parsimonious model to forecast the population of Nigeria for the next 3 decades. The model predicts that by 2050, Bangladesh's population would be approximately, 222 778 000; unless and until more stern population control measures are implemented in Bangladesh. This clearly shows that indeed population growth is a real threat to the future of Bangladesh especially considering the fact that Bangladesh is currently experiencing high levels of unemployment and poverty is widespread. These findings are particulary important for the government of Bangladesh as well as donor organisations, especially when it comes to planning for the future.

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