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Statistical Study of Gross Domestic Product in Some African Countries

Maysoon A. Sultan*

Department of Mathematics, Faculty of Science, University of Hafr Al Batin, Saudi Arabia

*Correspondence: maisona@uhb.edu.sa (Dr. Maysoon A. Sultan, Associate Professor, Department of Mathematics, Faculty of Science, University of Hafr Al Batin, Saudi Arabia).

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Abstract

The primary objective of this study is to identify the most effective models for predicting Gross Domestic Product (GDP) using the Auto-Regressive Integrated Moving Average (ARIMA) approach. The dataset analysis includes annual GDP figures from 1960 to 2023, focusing on countries in Africa with the highest GDPs, which are South Africa, Egypt, Kenya, and Ethiopia. The findings indicate that ARIMA is suitable for forecasting GDP in these African countries, with specific model parameters, which are as follows: South Africa ARIMA (5,1,1), Egypt ARIMA (14,1,8), Kenya ARIMA (14,1,13), and Ethiopia ARIMA (1,1,8). The models are appropriate to predict because it exhibits no significant autocorrelation in residuals, fit the historical data well, and pass standard diagnostic tests for time-series adequacy by using Theil Inequality Coefficients, BIA Proportions, Variance Proportions, and Mean Absolute Errors. The forecast results from these models indicate that South Africa is expected to have the highest GDP size over the next five years (2024-2028), but with a moderate annual growth rate of 6.2%. Both Egypt and Kenya are expected to develop strong growth of over 7.5% annually. On the other hand, Ethiopia is projected to show remarkable growth of 35.7% over the next five years.

Keywords: Time series, GDP, Statistical, Forecast, ARIMA, Economic indicator, African countries.

1. Introduction

The Gross Domestic Product (GDP) is an economic indicator that reflects the full market value of all final goods and services produced within a country over a certain timeframe, which is typically one year. This value is calculated by combining the monetary worth of these goods and services, resulting in the GDP. There are several techniques that exist for calculating GDP, which include the value-added method and expenditure methods. As it is known that GDP is one of the key economic indicators, it illustrates the state of economic activities and serves as a means to assess economic performance. Additionally, it aids in forecasting other indicators li ke inflation and unemployment (Carter Hill R., *et al.*, 2011; Islam and Alam, 2019; S. Dutta, 2022). GDP analysis is used to reveal the African continent's wide economic potential, marked by performance variety in its 54 countries. Some African economies are always classified among the fastest despite the challenges of political infrastructure, political instability in certain regions, and weakness of external shocks (International Monetary Fund, 2023). However, GDP figures do not reflect the real picture of economic welfare.

In an effort to examine the GDP of African countries representing geographical, demographic, and econo-

mic diversity, the focus was placed on certain African countries that recorded the highest GDP in recent years and are considered the most politically stable and supportive of foreign investment. Understanding and studying the GDP of these countries can provide valuable insights of local economies and economic trends thereby, supporting sustainable economic development. Ethiopia is one of the fastest-growing economies in Africa, with a large population and a strategic geographic location. Egypt, with its diverse economy, holds a pivotal position in the Middle East and Africa, coupled with a substantial population. South Africa stands as one of Africa's largest economies, strategically located at the continent's southern tip. Kenya serves as a key economic hub in East Africa, characterized by a sizable population and significant geographic importance. Thus, the countries under this study represent the geographical diversity spanning from North to South Africa, showcasing significant economic diversity. They exhibit notable economic growth, making them a focal point for investors and economists. Their strategic geographic location in Africa makes them crucial for regional trade and investment. They constitute important consumer markets for products and services, as they characterise with large populations. These countries also enjoy relative political stability, creating a conducive environment for investment and economic development.

There are some important studies in GDP such as "Trade globalization, green taxation and CO_2 reduction in sub-Saharan Africa", this study explored trade globalization interrelation, green imposition, and GDP. The item underlies economic unfairness with global systems while on the other hand, rewarding green fixed policies that can sustain long-term sustainability. The research suggested that the green and commercial tax policies can significantly affect GDP performance, especially in the context of economic and environmental reforms. It also revealed that the economies of sub-Saharan Africa are still developing strong mechanisms and climate of weather, but incur useless of envelopes of environmental costs (Omodero, 2019). "The impact of financial development and trade openness on economic growth in emerging markets", this research examined the impact of financial development and trade liberalization on GDP growth in 19 emerging economies that are primarily located in Asia and Africa. By using dynamic panel data analysis spanning 1990-2016, the study found that both financial development and trade openness significantly boost GDP growth, and therefore it supported the notion that strong financial systems and open trade policies are key drivers of sustainable economic growth in developing countries (Sahoo, *et al.,* 2019). "Forecasting the GDP in the United States by Using ARIMA Model", this study used the Autoregressive Integrated Moving Average (ARIMA) model to predict the growth of Gross Domestic Product (GDP) in the United States. The analysis covered 93 years of GDP data (1929-2022), and it concluded that the ARIMA (1,1,1) model is a reliable tool for predicting GDP growth in the United States (Sultan MA., 2023). "Exports, government debt and economic growth in sub-Saharan Africa", this research focused on the impact of government debt on export-led growth in 44 sub-Saharan African countries from 2004 to 2023. It suggested that sub-Saharan African countries need to manage their debt levels to achieve export-led growth and recommended fiscal adjustments to reduce debt (Mensah, E., *et al.,* 2024). "Sustainable development in African countries: evidence from the largest economies", the study examines the impact of various factors on sustainability in 15 major African economies from 1999 to 2019. The findings highlighted the importance of: Education, Poverty, and ICT development reduction. It concluded that increasing trade liberalization volumes are linked to reduced sustainability.

Furthermore, higher GDP per capita is associated with lower sustainability which is potentially due to unsustainable consumption patterns. So it recommended policies focusing on education, poverty reduction, and sustainable entrepreneurship to promote sustainable development in African countries (Angélica *et al.,* 2024). "Revisiting the Gains from Trade in EMDEs: The Case of Selected East Asian and East African Economies", the paper presented an exact price index to assess the welfare gains resulting from increased variety. According to the findings, African countries developed average welfare gains of 5.47% of GDP (0.20% per year) which is from 1995 to 2021, Asian countries (excluding Bhutan) gained 3.46% (0.13% annually). While on the other hand, some countries developed the highest welfare gains over the period including Bhutan, Mongolia, Rwanda, and Mozambique

(Battogtvor, *et al.,* 2025). "Sustainable development in Africa: A comprehensive analysis of GDP, CO_2 emissions, and socio-economic factors", this research examined the relationship between CO_2 emissions, economic growth, and socio-economic factors in 36 African countries from 1990 to 2020. It recommended integrated policies focusing on: renewable energy adoption, sustainable urbanization, and green growth strategies to achieve a balance between economic growth and environmental sustainability in Africa (Habimana Simbi, *et al.,* 2025). "The contribution of tourism on GDP growth and sustainable tourism development in Africa", this paper examined the contribution of tourism to GDP growth in 6 African countries (Egypt, Kenya, Morocco, South Africa, Tunisia, and Uganda) from 1999 to 2020. It provided insights into the complex relationship between tourism and GDP growth, highlighting implications for policymaking and economic development strategies in these African countries (Seraj, *et al.,* 2025). "Real-time forecasting of German GDP based on a large factor model with monthly and quarterly data", this paper presented a factor model for real-time short-term forecasting of GDP growth, utilizing a large set of monthly and quarterly time series.

The model employed an EM algorithm with a principal components estimator to handle mixed frequencies and missing data. Using a novel German real-time dataset, the model's forecast accuracy is evaluated through a recursive experiment, assessing the impact of revisions, timely monthly observations, and comparing its performance to a quarterly-data-based factor model (Christian Schumacher, *et al.,* 2008). "Forecasting and nowcasting real GDP: Comparing statistical models and subjective forecasts", this study compared twelve statistical models and professional analysts' forecasting abilities for the euro area and its five largest countries (1996–2011). Summarizing information in a few factors and using all available monthly observations improves fore-casting. The dynamic factor model excels, and analysts' judgmental forecasts contain valuable information that can enhance mechanical forecasts (W. Jos Jansen, *et al.,* 2016; Sultan, 2023).

This paper provides a comparative statistical analysis of GDP growth patterns across selected African countries using time series models, addressing a gap in cross-country studies that often focus on a single economy. Furthermore, as we introduced the background information and reviewed related literature in this section, the second section will describe the data and methodology, the third section will present the empirical results and discussion, and the last section will conclude with key findings, limitations, and recommendations for future research.

2. Methodology

This dataset provides comprehensive historical data on Gross Domestic Product (GDP) at a global level. The sample is about annual data that consists of Gross Domestic Product spanning from 1960 to 2023, categorized by African countries with the highest GDP in 2023: South Africa, Egypt, Kenya, and Ethiopia. This dataset is created from https://www.kaggle.com/datasets/stealthtechnologies/gdp-growth-of-african-countries. The data were analyzed with Econometrics Views (EViews).

ARIMA (Auto-Regressive Integrated Moving Average) is a statistical model used for forecasting and analyzing time series data. It is a combination of three components:

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- An Autoregressive (AR) Process: let Y_t represent the logged GDP at time t. Model Y_t as:

$$Y_t = c + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \cdots + \alpha_p Y_{t-p} + u_t \quad (1)$$

Where, c is a constant term representing the intercept, $(\alpha_1, \alpha_2, \ldots, \alpha_p)$ are the coefficients and where u_t is an uncorrelated random error term with zero mean and constant variance σ^2. In which case Y_t is p th-order autoregressive, AR(p) process.

- A Moving Average (MA) Process: It is simply a linear combination of white noise error terms

$$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \cdots + \beta_q u_{t-q} \quad (2)$$

  Where, $\beta_0, \beta_1, \ldots, \beta_q)$ are the coefficients.
- Integration (I): accounts for non-stationarity in data by differencing.

So, the original time series is ARIMA (p,d,q) which is an autoregressive integrated moving average time series where p denotes the number of autoregressive terms, d is the number of times the series has to be

differenced before it becomes stationary and q is the number of moving average terms (Gujarati, *et al.*, 2009). Box-Jenkins (BJ) methodology is used to identify and estimate a statistical model which can be interpreted as the process that generated the sample data. In this study, we apply the following three steps of the (BJ) methodology:

Step 1: Identification & Estimation: which is, finding out the appropriate value of *p, d* and *q*

Step 2: Diagnostic checking: The researcher will select the optimal ARIMA (p, d, q) model based on the following criteria: larger significant coefficients, highest R-squared value, and Smallest values of: Akaike Information Criterion (AIC), Schwarz Criterion (SC), SIGMASQ (Box G.E.P., *et al.*, 2015; Carter Hill R., *et al.*, 2011).

Step 3: forecasting inside and outside the sample series

The ARIMA model was applied over 64 years, utilizing a stationarity test (Augmented Dickey-Fuller unit root test) on GDP series, as well as autocorrelation and partial autocorrelation function graphs to determine the appropriate differencing and transformation to achieve stationarity. The Auto-Regressive Integrated Moving Average (ARIMA) is primarily used for:

- Comprehensive analysis of African GDP.
- Determining the optimal model for predicting GDP in African States.
- Forecasting the African GDP growth over the next five years.

3. Results and Discussion

This section presents a comparative statistical analysis of GDP growth patterns across selected African countries using time series models and states the empirical findings of the time series analysis. First, we will describe the annual data series for the selected African countries.

Then, we will examine the stationarity properties of each series using the Augmented Dickey-Fuller test to determine the appropriate order of differencing for the ARIMA models. After that, we will identify and estimate the optimal ARIMA (p, d, q) model for each country based on information criteria and diagnostic checks and then finally, we will evaluate the goodness-of-fit of the estimated models and present short-term forecasts of GDP to highlight future trends. The results of these analyses are presented in **Table 1-13**. The following table summarize the descriptive statistics of the highest GDP in Africa:

Table 1: Descriptive Statistics for Annual Data of the Highest Gross Domestic Product in Africa During 1960 – 2023.

State	Mean	Max	Min.	Std. Dev.
South Africa	169559736264.17	458199000000.00	8748596501.00	144365097416.73
Egypt	105042363696.25	476747720364.74	4035461921.92	126358020868.58
Kenya	24500987903.62	113420000000.00	791265459.50	32780407148.73
Ethiopia	23806454344.11	163698000000.00	1610511694.00	35058948179.42

The dataset in **Table 1** demonstrates a statistical summary of Gross Domestic Product (GDP) figures for these African countries: South Africa, Egypt, Kenya, and Ethiopia.

South Africa records the highest GDP average at approximately $169.56 billion. Egypt ranks second in GDP average ($105.04 billion) but also shows considerable variability. On the other hand, Kenya and Ethiopia report significantly lower GDP averages ($24.50 billion and $23.81 billion, respectively), reflecting smaller economies. Although their standard deviations are lower in absolute terms, they are relatively high compared to their means, suggesting notable year-to-year variation. Overall, the data captures the disparities in economic scale and stability across these four African countries. The following figure describes the original series of the African sample:

As shown above **Fig. 1**, the original series has an exponential shape in all sample space of African countries. In addition, the Augmented Dickey-Fuller Test results are not statistically significant at 1%, 5%, 10% level, as shown in the table below:

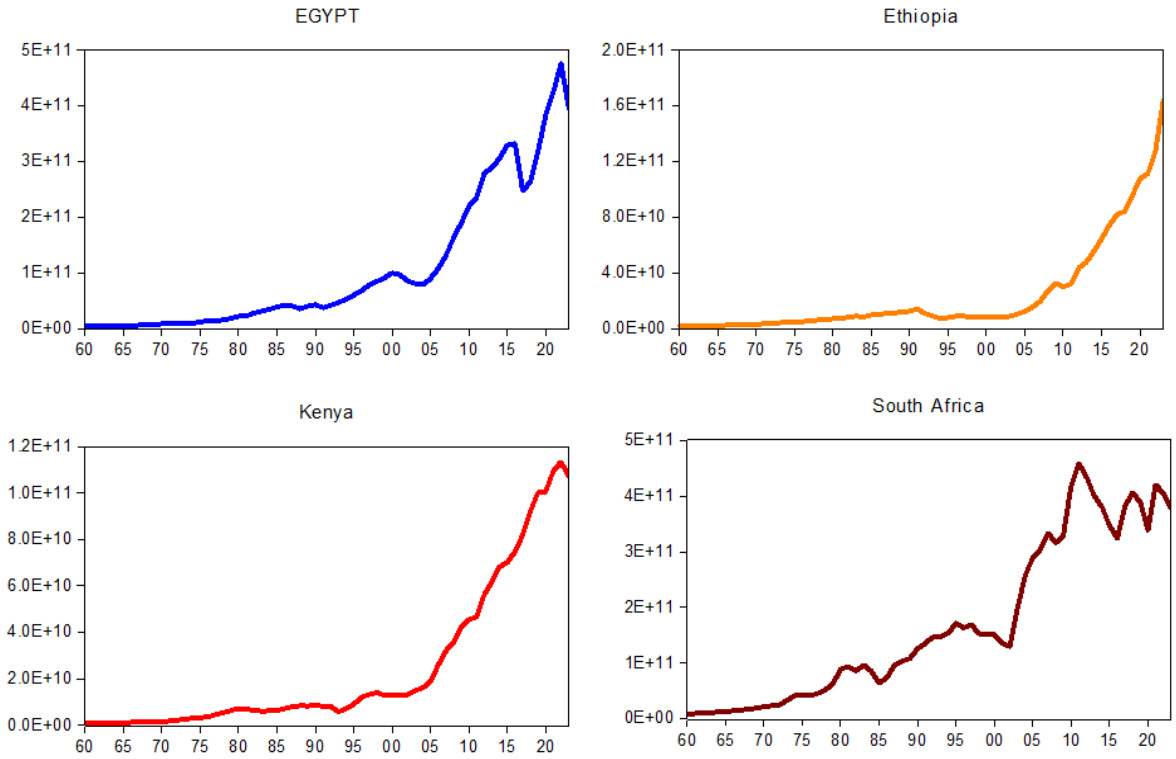


Fig. 1: Annual Data on the Highest Gross Domestic Product in African Sample Series During, 1960 – 2023.

Table 2: Augmented Dickey-Fuller Test for Unit Root in Level.

Include in test equation	South Africa	Egypt	Kenya	Ethiopia
Intercept	-0.388127 (0.9043)	4.699971 (1.0000)	1.277580 (0.9983)	3.433956 (1.0000)
Trend and Intercept	-2.303640 (0.4257)	3.120984 (1.0000)	0.781630 (0.9997)	3.291504 (1.0000)
None	1.116847 (0.9300)	5.126504 (1.0000)	1.784424 (0.9812)	3.247760 (0.9996)

We will eliminate the nonstationary by using the logarithm of the series, as shown in the table below:

Table 3: Augmented Dickey-Fuller Test on Logarithms.

Include in test equation	Log (South Africa)	Log (Egypt)	Log (Kenya)	Log (Ethiopia)
Intercept	-2.374643 (0.1530)	-0.611229 (0.8602)	-0.768633 (0.8207)	0.866002 (0.9944)
Trend and Intercept	-1.813744 (0.6862)	-2.889813 (0.1729)	-2.242231 (0.4583)	-0.740831 (0.9652)
None	3.674455 (0.9999)	5.400979 (1.0000)	3.278960 (0.9996)	2.887822 (0.9989)

The Augmented Dickey-Fuller statistics of LGDP showed that the results are not statistically significant at 1%, 5%, 10% levels for all African sample series, hence, we conclude that the LGDP series have a unit root and is still non-stationary. The following table shows the result for Unit Root test after using 1st Difference of the logarithm:

Table 4: Augmented Dickey-Fuller Test for Unit Root in 1st Difference.

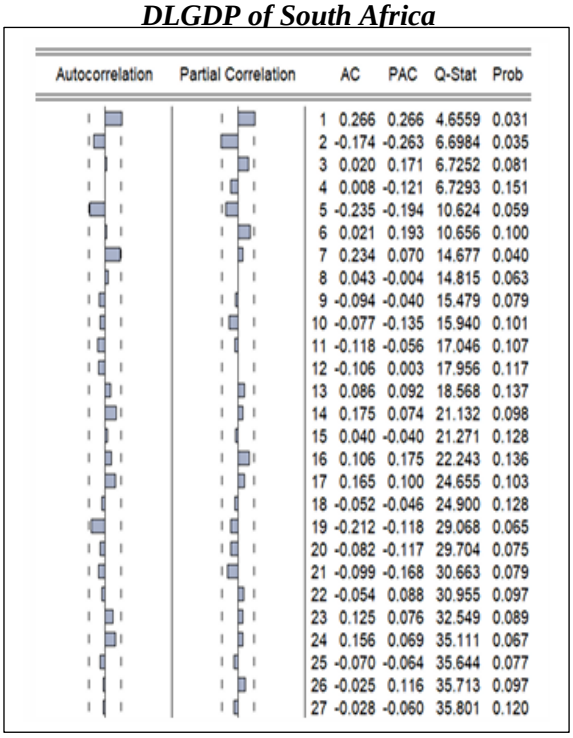
Include in test equation	D (Log (South Africa))	D (Log (Egypt))	D (Log (Kenya))	D (Log (Ethiopia))
Intercept	-5.965416 (0.0000)	-5.787415 (0.0000)	-5.547789(0.0000)	-4.543851 (0.0005)
Trend and Intercept	-6.470204 (0.0000)	-5.735541(0.0001)	-5.501655 (0.0001)	-4.706794 (0.0017)
None	-5.046131 (0.0000)	-4.436767 (0.0000)	-4.082074 (0.0001)	-3.373392 (0.0011)

Table 4, shows that all the series are stationary after 1st Difference of the LGDP at 1%, 5%, 10% levels of significant.

The following table show the Correlogram of 1st difference of the LGDP for South Africa, Egypt, Kenya and Ethiopia:

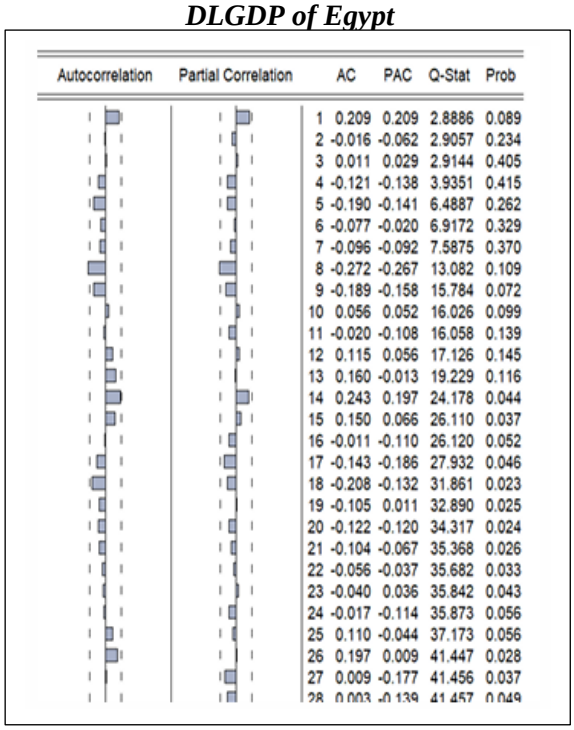
Table 5: Correlogram of 1st Difference of the LGDP for the African Sample Series.

DLGDP of South Africa



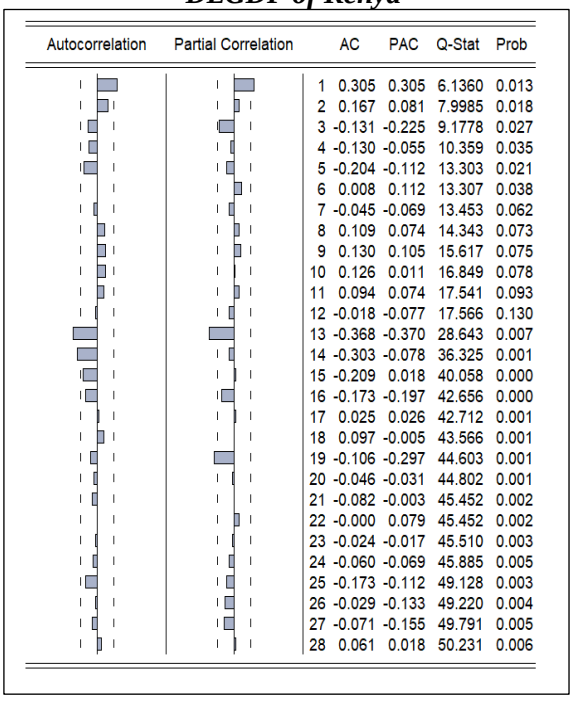
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.266	0.266	4.6559	0.031
		2	-0.174	-0.263	6.6984	0.035
		3	0.020	0.171	6.7252	0.081
		4	0.008	-0.121	6.7293	0.151
		5	-0.235	-0.194	10.624	0.059
		6	0.021	0.193	10.656	0.100
		7	0.234	0.070	14.677	0.040
		8	0.043	-0.004	14.815	0.063
		9	-0.094	-0.040	15.479	0.079
		10	-0.077	-0.135	15.940	0.101
		11	-0.118	-0.056	17.046	0.107
		12	-0.106	0.003	17.956	0.117
		13	0.086	0.092	18.568	0.137
		14	0.175	0.074	21.132	0.098
		15	0.040	-0.040	21.271	0.128
		16	0.106	0.175	22.243	0.136
		17	0.165	0.100	24.655	0.103
		18	-0.052	-0.046	24.900	0.128
		19	-0.212	-0.118	29.068	0.065
		20	-0.082	-0.117	29.704	0.075
		21	-0.099	-0.168	30.663	0.079
		22	-0.054	0.088	30.955	0.097
		23	0.125	0.076	32.549	0.089
		24	0.156	0.069	35.111	0.067
		25	-0.070	-0.064	35.644	0.077
		26	-0.025	0.116	35.713	0.097
		27	-0.028	-0.060	35.801	0.120

DLGDP of Egypt



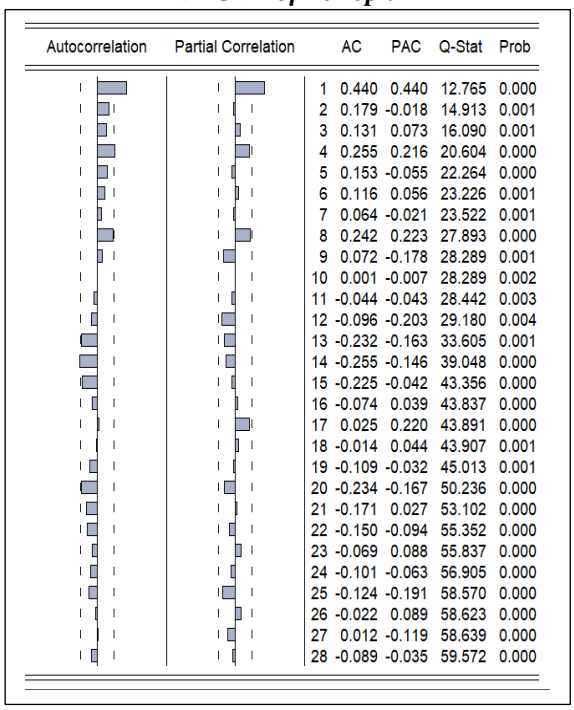
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.209	0.209	2.8886	0.089
		2	-0.016	-0.062	2.9057	0.234
		3	0.011	0.029	2.9144	0.405
		4	-0.121	-0.138	3.9351	0.415
		5	-0.190	-0.141	6.4887	0.262
		6	-0.077	-0.020	6.9172	0.329
		7	-0.096	-0.092	7.5875	0.370
		8	-0.272	-0.267	13.082	0.109
		9	-0.189	-0.158	15.784	0.072
		10	0.056	0.052	16.026	0.099
		11	-0.020	-0.108	16.058	0.139
		12	0.115	0.056	17.126	0.145
		13	0.160	-0.013	19.229	0.116
		14	0.243	0.197	24.178	0.044
		15	0.150	0.066	26.110	0.037
		16	-0.011	-0.110	26.120	0.052
		17	-0.143	-0.186	27.932	0.046
		18	-0.208	-0.132	31.861	0.023
		19	-0.105	0.011	32.890	0.025
		20	-0.122	-0.120	34.317	0.024
		21	-0.104	-0.067	35.368	0.026
		22	-0.056	-0.037	35.682	0.033
		23	-0.040	0.036	35.842	0.043
		24	-0.017	-0.114	35.873	0.056
		25	0.110	-0.044	37.173	0.056
		26	0.197	0.009	41.447	0.028
		27	0.009	-0.177	41.456	0.037
		28	0.003	-0.139	41.457	0.049

DLGDP of Kenya



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.305	0.305	6.1360	0.013
		2	0.167	0.081	7.9985	0.018
		3	-0.131	-0.225	9.1778	0.027
		4	-0.130	-0.055	10.359	0.035
		5	-0.204	-0.112	13.303	0.021
		6	0.008	0.112	13.307	0.038
		7	-0.045	-0.069	13.453	0.062
		8	0.109	0.074	14.343	0.073
		9	0.130	0.105	15.617	0.075
		10	0.126	0.011	16.849	0.078
		11	0.094	0.074	17.541	0.093
		12	-0.018	-0.077	17.566	0.130
		13	-0.368	-0.370	28.643	0.007
		14	-0.303	-0.078	36.325	0.001
		15	-0.209	0.018	40.058	0.000
		16	-0.173	-0.197	42.656	0.000
		17	0.025	0.026	42.712	0.001
		18	0.097	-0.005	43.566	0.001
		19	-0.106	-0.297	44.603	0.001
		20	-0.046	-0.031	44.802	0.001
		21	-0.082	-0.003	45.452	0.002
		22	-0.000	0.079	45.452	0.002
		23	-0.024	-0.017	45.510	0.003
		24	-0.060	-0.069	45.885	0.005
		25	-0.173	-0.112	49.128	0.003
		26	-0.029	-0.133	49.220	0.004
		27	-0.071	-0.155	49.791	0.005
		28	0.061	0.018	50.231	0.006

DLGDP of Ethiopia



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.440	0.440	12.765	0.000
		2	0.179	-0.018	14.913	0.001
		3	0.131	0.073	16.090	0.001
		4	0.255	0.216	20.604	0.000
		5	0.153	-0.055	22.264	0.000
		6	0.116	0.056	23.226	0.001
		7	0.064	-0.021	23.522	0.001
		8	0.242	0.223	27.893	0.000
		9	0.072	-0.178	28.289	0.001
		10	0.001	-0.007	28.289	0.002
		11	-0.044	-0.043	28.442	0.003
		12	-0.096	-0.203	29.180	0.004
		13	-0.232	-0.163	33.605	0.001
		14	-0.255	-0.146	39.048	0.000
		15	-0.225	-0.042	43.356	0.000
		16	-0.074	0.039	43.837	0.000
		17	0.025	0.220	43.891	0.000
		18	-0.014	0.044	43.907	0.001
		19	-0.109	-0.032	45.013	0.001
		20	-0.234	-0.167	50.236	0.000
		21	-0.171	0.027	53.102	0.000
		22	-0.150	-0.094	55.352	0.000
		23	-0.069	0.088	55.837	0.000
		24	-0.101	-0.063	56.905	0.000
		25	-0.124	-0.191	58.570	0.000
		26	-0.022	0.089	58.623	0.000
		27	0.012	-0.119	58.639	0.000
		28	-0.089	-0.035	59.572	0.000

The Correlograms in **Table 5** shows the auto-correlation (AC) and partial autocorrelation (PAC) functions for the first-differenced log (GDP) series, DLGDP. The Q-statistics in Correlogram of South Africa are significant in some AC and PAC, rejecting the null hypothesis of no autocorrelation up to each lag.

The autocorrelation DLGDP function shows mixed positive and negative correlations, with significant spikes at lags 1,2,7. The PAC highlights notable values at lag 1,2 and 6. Hence, the final order 1, 2, 5 autoregressive moving average pre-estimation is performed on South Africa series. The following table show the estimated model of South Africa ARIMA:

Table 6: Estimated Model of ARIMA (p,d,q) of South Africa.

(p,d,q)	Sig of par.	R-squared	F-statistic	Prob (F-statistc)	Akaike info criterion	Schwarz criterion	Durbin-Watson stat	SIGMASQ
(1,1,1)	1	0.137894	3.145692	0.031682	-1.360237	-1.224165	2.021783	0.013189
(1,1,2)	3	0.148575	3.431862	0.022613	-1.372250	-1.236178	1.973158	0.013026
(2,1,1)	2	0.157004	3.662831	0.017251	-1.381562	-1.245490	1.967534	0.012897
(2,1,2)	1	0.031768	0.645266	0.589027	-1.246400	-1.110328	1.330250	0.014813
(1,1,5)	3	0.180296	4.325745	0.008000	-1.398734	-1.262662	1.818372	0.012540
(5,1,1)	**3**	**0.208623**	**5.184537**	**0.003018**	**-1.437833**	**-1.301761**	**2.052662**	**0.012107**
(2,1,5)	2	0.100310	2.192711	0.098383	-1.312211	-1.176139	1.269833	0.013764
(5,1,2)	1	0.078205	1.668515	0.183532	-1.292082	-1.156010	1.289635	0.014102

In the above table, the optimal model was selected according to number of significant parameters, R-squared, Akai Info. Criterion, Schwarz Criterion, Durbin-Watson stat and SIGMASQ. Model ARIMA (1,1,1), ARIMA (2,1,2) and ARIMA (5,1,2) were excluded to the low value of R-squared and low number of significant model parameters. We estimated the ARIMA models with q=7 and p=6, but they are excluded due to the lowest R-squared as well as no significant parameters. By comparing the rest of the model, we conclude that ARIMA (5,1,1) is the best model that satisfy highest R-squared value and the lowest values of the Akai Info. Criterion, Schwarz Criterion and SIGMASQ with significant values in all parameters. In **Table 6**, Q-statistics in Correlogram of Egypt, the AC values show significant spikes at lags 1,8 and 14 with Q-stat probabilities less than 0.05 from 18 up to 28, suggesting potential autoregressive behaviour at those lags. The PAC values help in identifying the direct effect of specific lags and hence pointing to notable influences at lags 1, 8, and 14. Therefore, the final order 1, 8, 14 autoregressive moving average pre-estimation is performed on Egypt series. The following table show the estimated model of Egypt ARIMA:

Table 7: Estimated Model of ARIMA (p,d,q) of Egypt.

(p,d,q)	sig	R-squared	F-statistic	Prob (F-statistc)	Akaike info criterion	Schwarz criterion	Durbin-Watson stat	SIGMASQ
(1,1,1)	1	0.058639	1.225069	0.308632	-1.622977	-1.486905	1.874878	0.010161
(1,1,8)	2	0.167743	3.963861	0.012150	-1.718027	-1.581955	1.857747	0.008983
(8,1,1)	1	0.137830	3.143982	0.031746	-1.697057	-1.560985	1.899621	0.009306
(8,1,8)	1	0.161169	3.778652	0.015070	-1.703468	-1.567396	1.657325	0.009054
(14,1,8)	**2**	**0.215578**	**5.404860**	**0.002359**	**-1.759239**	**-1.623167**	**1.770775**	**0.008467**
(8,1,14)	1	0.172874	4.110438	0.010253	-1.723770	-1.587698	1.685860	0.008928
(14,1,14)	1	0.117747	2.624735	0.058783	-1.657013	-1.520941	1.597401	0.009523
(1,1,14)	1	0.135127	3.072714	0.034537	-1.681120	-1.545048	1.864477	0.009335
(14,1,1)	1	0.121694	2.724914	0.052178	-1.674344	-1.538272	1.887012	0.009480

Table 7 shows that an optimal model is ARIMA (14,1,8) due to the highest R-squared value and the lowest values of the Akai Info. Criterion, Schwarz Criterion and SIGMASQ with significant value parameters. In **Table 5**, Q-statistics in Correlogram of Kenya, the AC values show significant spikes at lags q=1, q=13 and q=14, suggesting potential autoregressive behaviour at those lags. The PAC values help in identifying the direct effect of specific lags which points to notable influences at lags p=1 and p=13. Therefore, the final order 1, 13, 14 autoregressive moving average pre-estimation is performed on Kenya series. The following table show the estimated model of Kenya ARIMA:

Model ARIMA (1,1,1), ARIMA (13,1,13), ARIMA (14,1,14) and ARIMA (14,1,14) were excluded to the low value of R-squared and a low number of significant model parameters. By comparing the rest of the models, we conclude that ARIMA (14,1,13) is the best model that satisfy the highest R-squared value and the lowest values of Akai Info. Criterion, Schwarz Criterion and SIGMASQ with two significant value parameters.

Table 8: Estimated Model of ARIMA (p,d,q) of Kenya.

(p,d,q)	sig	R-squared	F-statistic	Prob (F-statistc)	Akaike info criterion	Schwarz criterion	Durbin-Watson stat	SIGMASQ
(1,1,1)	1	0.098734	2.154499	0.102970	-1.685143	-1.549071	1.984611	0.009546
(13,1,13)	1	0.195305	4.773246	0.004799	-1.753404	-1.617332	1.580070	0.008523
(1,1,13)	3	0.218707	5.505296	0.002110	-1.801528	-1.665456	2.022461	0.008275
(13,1,1)	2	0.192800	4.697399	0.005231	-1.773873	-1.637801	1.861447	0.008549
(13,1,14)	2	0.247418	6.465585	0.000738	-1.816311	-1.680239	1.585604	0.007971
(14,1,13)	**2**	**0.280529**	**7.668217**	**0.000207**	**-1.845431**	**-1.709359**	**1.655745**	**0.007620**
(14,1,14)	1	0.103810	2.278080	0.088859	-1.673364	-1.537292	1.625997	0.009492
(1,1,14)	2	0.129133	2.916185	0.041574	-1.712911	-1.576839	2.022825	0.009224
(14,1,1)	1	0.124129	2.787167	0.048455	-1.704008	-1.567936	1.912651	0.009277

The Correlogram of DLGDP in Ethiopia in **Table 5** show that the Q-statistic of AC and PAC are all significant, which rejects the null hypothesis of no autocorrelation up to each lag. Autocorrelation show significant values at lags q=1, q=4 and q=8, suggesting potential autoregressive behaviour at those lags. The PAC show significant values at lags p=1, p=4 and p=8. Therefore, the final order 1, 4, 8 autoregressive moving average pre-estimation is performed on Ethiopia series. The following table show the estimated model of Ethiopia ARIMA:

Table 9: Estimated Model of ARIMA (p,d,q) of Ethiopia.

(p,d,q)	sig	R-squared	F-statistic	Prob (F-statistc)	Akaike info criterion	Schwarz criterion	Durbin-Watson stat	SIGMASQ
(1,1,1)	2	0.204252	5.048020	0.003518	-1.809333	-1.673261	1.942113	0.008414
(1,1,4)	2	0.231292	5.917377	0.001339	-1.842528	-1.706455	1.899930	0.008128
(4,1,1)	3	0.237306	6.119112	0.001074	-1.847792	-1.711720	1.850665	0.008064
(1,1,13)	2	0.224328	5.687690	0.001724	-1.830603	-1.694531	1.919676	0.008201
(8,1,1)	2	0.254312	6.707180	0.000570	-1.863696	-1.727624	1.758413	0.007884
(1,1,8)	**3**	**0.278710**	**7.599294**	**0.000222**	**-1.896563**	**-1.760491**	**1.861044**	**0.007626**
(8,1,4)	1	0.121793	2.727451	0.052020	-1.702982	-1.566910	1.075919	0.009285
(4,1,8)	1	0.125372	2.819088	0.046652	-1.706672	-1.570600	1.081678	0.009248
(1,1,14)	2	0.242559	6.297958	0.000885	-1.846874	-1.710802	1.944308	0.008009
(4,1,14)	3	0.250654	6.578439	0.000654	-1.797927	-1.661854	1.303195	0.007923

By comparing the models in the above table, we conclude that ARIMA (1,1,8) is the best model that satisfy the highest R-squared values and the lowest values of Akai Info. Criterion, Schwarz Criterion and SIGMASQ with all demonstrating significant value parameters. The selected ARIMA Models are shown in **Table 10** below:

Table 10: Model Selection Criteria for Annual Data of the Highest Gross Domestic Product in Africa During 1960 – 2023.

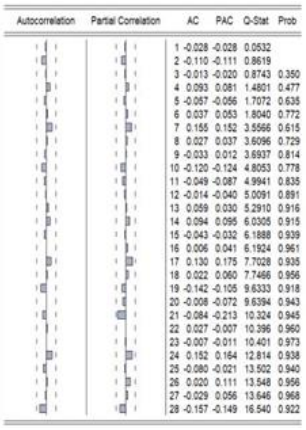
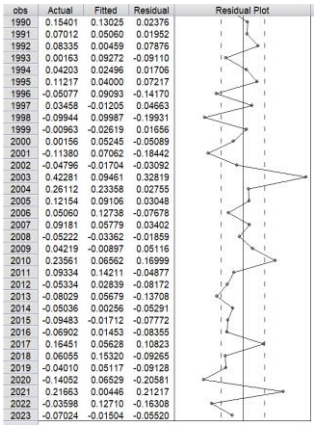
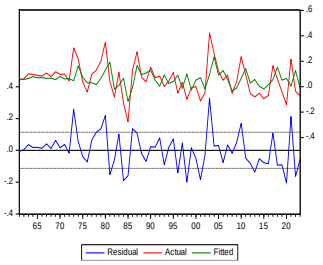
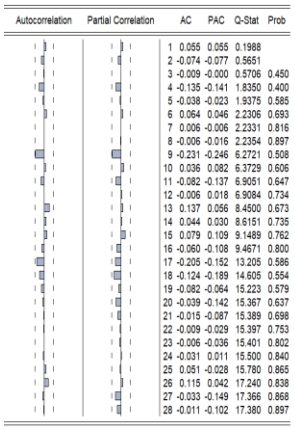
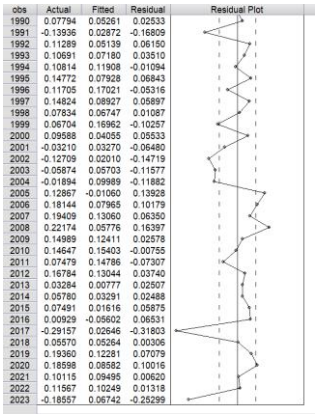
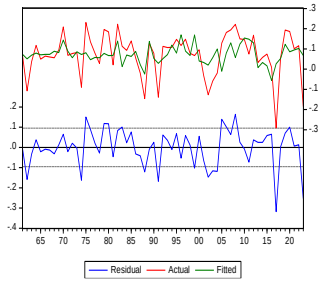
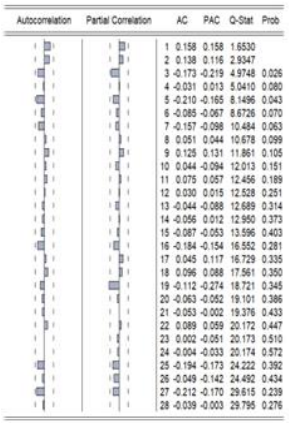
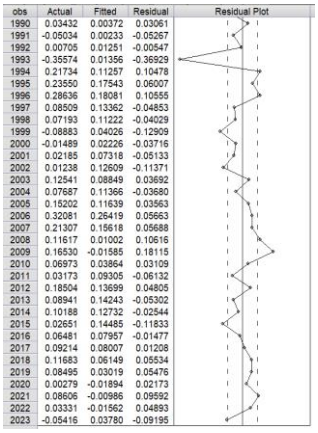
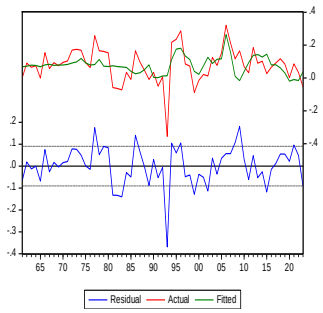
State	Dependent Variable	Selected ARIMA Model	Akaike info criterion	Schwarz criterion	Durbin-Watson stat	SIGMASQ
South Africa	D(log(South Africa))	(5,1,1)	-1.437833	-1.301761	2.052662	0.012107
Egypt	D(log(Egypt))	(14,1,8)	-1.759239	-1.623167	1.770775	0.008467
Kenya	D(log(Kenya))	(14,1,13)	-1.845431	-1.709359	1.655745	0.007620
Ethiopia	D(log(Ethiopia))	(1,1,8)	-1.896563	-1.760491	1.861044	0.007626

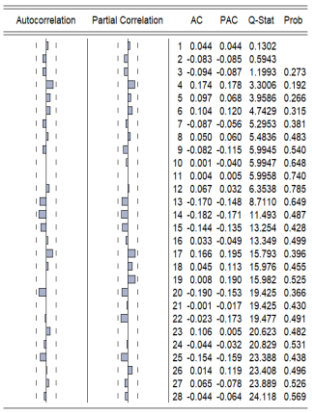
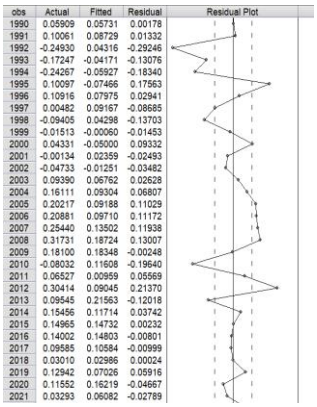
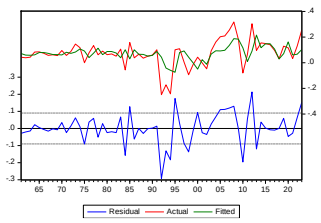
The models in **Table 10**, show that log-differenced GDP series generally follow stationary processes after differencing (d=1), as it was expected in macroeconomic time series. Durbin-Watson statistic values for all models are near 2 that indicate the absence of autocorrelation in residuals, which hence imply well-specified models. Ethiopia's model ARIMA (1,1,8) appears to be the most efficient

according to AIC and Schwarz criteria which hence, indicate a well-specified model. The Kenyan and Egyptian models are more complex each with high AR/MA orders, but they achieve better information criteria than South Africa's simpler model.

The following table verify Correlogram of residual, residual plot, and graph of (Residual - Actual – Fitted):

Table 11: The Residual Graph Annual Data of the Highest Gross Domestic Product in African Sample Series During 1960 – 2023.

State	*Correlogram of Residual*	*Residual Plot*	*Residual - Actual - Fitted*
South Africa			
Egypt			
Kenya			

State	*Correlogram of Residual*	*Residual Plot*	*Residual - Actual - Fitted*
Ethiopia			

The diagnostics presented in the above table is comprised of the correlogram of residuals, residual plots and actual versus fitted plots which provided strong evidence that the model of sample series are appropriate for forecasting. In the correlogram, AC and PAC values generally laid within the confidence bounds, indicating that the residuals behave like white noise. Q-statistic probabilities are mostly non-significant, with a probability greater than 0.05, which validates the model's specification. The residual plots show residuals fluctuating randomly around zero without discernible pattern or trends. This randomness confirms that the models are not systematic and hence it supports the assumption of homoscedasticity and independence of residuals, which are essential for reliable forecasting. All residuals in the correlograms, residual plots, actual and fitted graph are remaining within a stable range. In general, the selected models are appropriate for forecasting because it satisfies standard time-series diagnostic criteria and provide a good fit with reliable predictive performance. The following table verify the forecast inside the sample:

Table 12: Forecast Inside the Sample in 2023.

State	Actual	Fitted	Residual
South Africa	-0.07024	-0.01504	-0.05520
Egypt	-0.18557	0.06742	-0.25299
Kenya	-0.05416	0.03780	-0.09195
Ethiopia	0.25563	0.10270	0.15293

The above table shows that there is a difference between fitted and actual values with a low relative error range of 5% to 25%, indicating a good fitting effect of the models. The models also exhibit high predictive power, with the Theil Inequality Co-efficient values ranging from 0.005392 to 0.014054, Bias Proportions between 0.055865 and 0.553324, Variance Proportion values ranging from 0.000226 to 0.079735 and Mean Absolute Error values ranging from 0.190143 to 0.498021, suggesting that the GDP forecasting is significant and the models' forecasting ability is satisfactory.

Among the sample countries, South Africa and Kenya show the smallest residual value, indicating a close match between actual and predicted values. In contrast, Egypt experienced significant negative residuals, meaning the model overestimated performance. Ethiopia, however, shows a slightly higher positive residual value, suggesting that the model under predicted its strong growth. Overall, the data reveals varying levels of model accuracy across the countries, highlighting the importance of country-specific dynamics in economic forecasting. As verified in the following table:

By using Box-Jenkins for forecasting GDP for five years from 2024 to 2028, the results are shown in the table below:

Table 13: Forecast Outside the Sample.

State	2024	2025	2026	2027	2028
South Africa	455202506584.58	483572084421.68	513709733464.25	545725646680.78	579736882387.46
Egypt	377972641325.18	407157844243.93	438860724885.79	472679955796.28	509129569918.88
Kenya	125609885036.06	135733462155.92	146692611758.6	158634888724.08	171629644332.38
Ethiopia	195790955493.64	211333969063.94	228110876606.37	246219631638.93	265765963957.47

South Africa is expected to take the lead in GDP size over the next five years (2024-2028) but with a moderate annual growth rate of 6.2% hence, indicating steady economic expansion which is likely fuelled by its industrial and service sectors. Egypt is projected to experience robust growth at 7.7% annually, potentially driven by infrastructure development, energy investments, and rising consumption. Kenya shows a strong growth at 8.1% annually, adding roughly $10 billion each year despite its smaller economy hence, reflecting potential in tech, services, and agriculture. Furthermore, Ethiopia on the other hand demonstrates significant growth, with a 35.7% increase over five years, which is likely spurred by reforms, infrastructure, and demographic advantages.

Therefore, by 2028, Egypt is expected to take the lead in absolute GDP size ($509.12 billion), while Kenya will have the smallest economy. South Africa will remain the largest GDP but with slower growth compared to Egypt, Kenya, and Ethiopia.

4. Conclusion

The model's performance varies across countries: South Africa ARIMA (5,1,1), Egypt ARIMA (14,1,8), Kenya ARIMA (14,1,13), and Ethiopia ARIMA (1,1,8). The R-squared values are 0.208623, 0.215578, 0.280529, and 0.278710, respectively, indicating satisfactory fit. These models were selected based on the highest R-squared value and the lowest Akaike Info Criterion, Schwarz Criterion, and SIGMASQ values, with most parameters being significant. The diagnostics provided strong evidence that the models are appropriate for forecasting the sample series. They also exhibited high predictive power, with Theil Inequality Coefficient values ranging from 0.005392 to 0.014054, Bias Proportions between 0.055865 and 0.553324, Variance Proportions from 0.000226 to 0.079735, and Mean Absolute Error values from 0.190143 to 0.498021. These metrics suggest that the GDP forecasting is significant and the models' forecasting ability is satisfactory. This paper contributes to the literature on applied time series in economics. It provides a comparative statistical analysis of GDP across several African economies using a unified ARIMA framework, covering a consistent long-term period from 1960 to 2023, and it employs a comprehensive diagnostic approach to validate model adequacy. It offers practical out-of-sample forecasts that can inform policy discussions of economic planning in the region. This study primarily focuses on univariate ARIMA modelling, which provides a baseline for forecasting GDP based on historical patterns. Future studies may incorporate multivariate frameworks and external economic variables to capture additional dynamics through ARIMAX models, applying multivariate techniques such as VAR, and comparing ARIMA forecasts with machine learning approaches.

5. Acknowledgement

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6. Conflicts of Interest

The author declares no conflicts of interest

7. References

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