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Economic Growth Modelling in Africa: An Application of Bayesian Model Averaging

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Abstract:- The study seeks to model economic growth in Africa using the Bayesian Model Averaging technique. The dataset for the study is a pooled dataset spanning through 2010 to 2021 yearly for seven variables namely: Economic growth (GDP), inflation, unemployment, government consumption, food production,exchange rate and trade openness in 24 Africa economies.

The Bayesian Model Averaging technique is adopted having the capacity to extract the posterior inclusion probability under different model prior associated with g-priors attributed to different Bayesian Model Sampling Scheme.

Findings from the study shows that, in modelling economic growth in Africa, a BMA with Uniform model prior with EBL gprior is most plausible while on the basis of sub-regions, the most plausible BMA model is Uniform model prior with Hyper gprior having accounted for the highest Posterior Model Probability correlation value.

Bayesian models with other variants of g-prior should be explored for better detection of the true determinants of economic growth among feasible identified factors under consideration.

Keywords:- *Economic growth, g-prior, Posterior Model Prior, Posterior Inclusion Probability, BMA.*

I. INTRODUCTION/BACKGROUND OF THE STUDY

A welfare indicator of an economy is economic growth which measures the amount of goods and services made available via production over time. Amongst the prevailing constituents of economic growth in an economy are income distribution, productivity, and unemployment(Thurik & Thurik, 2010).The economy of a nation is considered to have grown when the nation's capital dividend by the total population of such a country increases sustainability (Akintoye, 2008).

The economic growth of an economy may be considered using the GDP of the economy. If the GDP of an economy increases, the country's economic growth is considered increased. Also, if there are an increase in the aggregate goods and services per person in an economy for a reasonable period of time say 5 years and above there are elements of economic growth(Khan & Senhadji, 2001).

In the light of panel data modelling, it is of interest to move from the notion of knowing beforehand the tactical means of parameter estimation without incorporating prior believe, while the prior believe is incorporated there is a great chance of being able to have a set of models having the same structure but different parameter components for capturing the inherent variation in the dependent variable. The application of Bayesian Inference to the problems of model selection, the combination of estimation and prediction that produces an easy model choice criteria and less risky prediction is the Bayesian Model Averaging (Fragoso & Neto, 2015).

Region-wise, economy activity has rebounded across Africa. Though, the dimension of recovery was not equally discovered among the different countries and the sub-regions. It is observed that countries which operate oil-exporting expand more strongly than those which operate oil-importing. Among all, West Africa and East Africa made a unique outperformance in 2010 (OECD, 2011).

Due to protectionist policies, the inter-African trade has been retarded among the countries and the regions to 17% compared to Europe, where an inter-regional trade is achieved at 69% (Landry & Usman, 2021).

Inflation as one of the determinants of economic growth in the literature is seen as the persistent, consistent and the continuous rise or increment in the general price level of a country (Akinsola & Odhiambo, 2017).

The stability of price is an essential determinant and perquisite for stable economy for it is equivalent to expected inflation rate that any economic policy would want to formulate policies around (Ayd, Esen, & Bayrak, 2016).

Considering the stand of countries as classified as industrialized, need be that the relationship between unemployment and economic growth be investigated in 2013. It was discovered that via the utility of panel regression analysis on a dataset for seven industrialized countries (G7) spanning through 2000 to 2011, economic growth is found to have significant effect on the decline in unemployment in three crisis period though during the immediate post-crisis era, the effect tends to be negative and led to a an increase impact level in relation to the crisis era (Ozei, Sezgin, & Topkaya, 2013).

In order to show specific determinants of a dependent variable such as economic growth for different regions, it worthwhile to apply the Bayesian model averaging. Their study used a panel dataset consisting of Asian, European, African, Caribbean, Petroleum exporting and American countries with identified nine predictors of economic growth in 126 countries spanning through 2010 to 2014. Results showed that the major predictors detected were fiscal policy trade openness, inflation rate and government consumption rate. Their further accounted that in Africa, unemployment rate has adverse effect on the economic growth, interest rate impacts economic growth positively whereas government consumption impose a negative impact on economic growth(Ogundumade & Adepoju, 2018).

The relationship between unemployment and economic growth was explored in 2018 using 7 western Balkan countries. The result from the study showed that unemployment influenced economic growth negatively by the application of effective effect model alongside the random effect pattern as well as the Hausman Taylor (Kukaj, 2018).

(Obansa, Okoroafor, Aluko, & E., 2013)examined the impact of exchange rate on the Nigerian economic growth for the period of 1970–2010. The result indicated that the exchange rate had a strong positive impact on economic growth. Thus, they found evidence that economic growth is significantly associated with real exchange rate depreciation.

Ignatius, Agus, and Long carried out a study on the dynamics of inflation, money growth, exchange rate and interest rate in Ghana. The study used the Distributed lag (ARDL) model for experimental analysis, and the study period was from 1998 to 2018. It was found that the exchange rate and inflation rates markedly affect money growth in both the short and long term and in the same direction(Long, Ignatius, & Yang, 2019).

II. DATA AND METHOD

A. *Data for the Study*

The data for the study includes 24 countries in Africaobserved over the period of 12 years which span through 2010 to 2022 across seven variables which comprise of Gross Domestic Product [GDP] as dependent and four independent variables (Inflation rate, exchange rate, unemployment rate, trade openness, government consumption, and food production). The dataset is an excerpt of the World Bank.

Table 1: Cross Sectional Units

1.	**North Africa:**	**Algeria,**	**Egypt,**	**Morocco,**	**Tunisia,**	**Sudan**
2.	**Central Africa:**	Angola,	Cameroon,	Congo,	Equatorial Guinea	Gabon.
3.	**Eastern Africa:**	Rwanda,	Kenya,	Zimbabwe,	Tanzania	
4.	**West Africa:**	Nigeria,	Senegal,	Ghana,	Cote D'Ivoire,	Cabo Verde
5.	**Southern Africa:**	Botswana,	Lesotho,	Eswatini,	Namibia,	South Africa

B. *Methods*

The methods explore include the those of exploratory data analysis using diverse form of data presentation which includes the multi-dimensional scatter plot, and boxplot for panel data framework and data summarization techniques. On the account of the multi-dimensional plot, the plot is made up of data points signified by the cross-sections of interest and the more clustered the data points across different cross-sections, the higher the dependency across the observed cross-section.

The set of preliminary analysis prior to the Bayesian Model Averaging (BMA) are the test of normality, stationarity test and cross-dependence among panels in the longitudinal analysis framework.

In this study, the panel stationarity test to be applied are Pesaran and Shin (IPS) (Im, Pesaran, & Shin, Testing for Unit Roots in Heterogeneous Panels, 1997) and (Im & Pesaran, 2003) while estimating first an autoregressive (AR) process of the variables as follow:

$$y_{it} = \rho_i \sum_{j=1}^{P_i} y_{it-j} + x_{it}^{'}\delta + v_{it}$$

Note that y_{it} denotes the variable of interest for which the test of stationarity is to be carried out and x_{it} denotes other control variables including individual trends and fixed effect.

- *The Bayesian Model Averaging*

Let there exist independent random samples of size of n from the normal linear regression model with constant term denoted by β_0 with k regressors in a matrix X of dimension $n \times k$ coupled with an identically independently distributed error term ε that is normal in nature having variance $\sigma^2 = (h^{-1})$.

Suppose there is a model j such that $j = 1, \dots, M$ ($M = 2^k$ $plausible\ models$) with regressors defined as X_j and for choice of $0 < k_j < K$ where k_j is the count or umber of the regressors in the specific model j. A model of the form can then be envisioned.

$$y = \beta_{0i_n} + X_j B_j + \varepsilon; \quad \varepsilon \sim N(0, h^{-1}I)$$

In the Bayesian domain, interest might be in a variable with β_j coefficient across all the model space, thus it is worthwhile to succinctly define the posterior distribution of the variable attributed to the available data as follows:

$$P(\beta_j|D) = \sum_{j=1}^{2^k} P(\beta_j|D, M_j)\, P(M_j|D)$$

where D denotes the sample data.

The model above is the defined as the mixture of the posterior distribution of the variable of interest with respect to the j models having a weighted probability model expressed as $P(M_j|D)$.

The weighted probability model could therefore be given as

$$P(M_j|D) = \frac{P(D|M_j)P(M_j)}{\sum_{j=1}^{2^k} P(D|M_j)P(M_j)} = P(D|M_j)P(M_j)\left[\sum_{j=1}^{2^k} P(D|M_j)P(M_j)\right]^{-1}$$

The prior probability that the true model is M_j is given by $P(M_j)$ with the marginal likelihood expressed as

$$P(D|M_j) = \int_0^\infty P(D|\beta_0, \beta_j, h^{-1}, M_j)\, P(\beta_0, \beta_j, h^{-1}|M_j) d\beta_0, d\beta_j, dh^{-1}$$

The model precision is measured or accounted for by h and the likelihood of the data is signified by $P(D|\beta_0, \beta_j, h^{-1}, M_j)$ while the prior distribution for model parameters is denoted by $P(\beta_0, \beta_j, h^{-1}|M_j)$

In this framework, BMA has the ability to extract the posterior inclusion probability (PIP) of a given regressor by taking the sum of the probabilities of the posterior model across the entire models having that regressor.

Hence, the Bayes factor can be derived by introducing g parameter prior to the model above and by taking the ratio we have the Bayes factor defined as:

$$B_{jr} = \left(\frac{g_j}{g_j+1}\right)^{\frac{k_j}{2}} \left(\frac{g_r+1}{g_j}\right)^{\frac{k_j}{2}} \left[\frac{\frac{1}{g_r+1} y^1 Q X_r y + \frac{g_r}{g_r+1}(y-\bar{y}_{in})^1(y-\bar{y}_{in})}{\frac{1}{g_j+1} y^1 Q X_j y + \frac{g_j}{g_j+1}(y-\bar{y}_{in})^1(y-\bar{y}_{in})}\right]^{\frac{n-1}{2}}$$
$$for\ k_j, k_r \geq 0$$

➢ *Nature of Prior in Bayesian Model Averaging*

There are two forms of prior in the BMA. They are parameter prior and the model prior. While the latter reflects or accounts for the prior believe about the model as specified by the researcher the parameter prior aids the determination of degree of importance associated with the prior precision using the g-structure.

- Model Prior

Eliciting a uniform prior probability is a common choice for any given model in the model space in order to elucidate the absence of prior information via the rule of thumb. Other forms of model prior include the binomial, beta-binomial and their counterparts in relation to custom-prior inclusion probabilities.

In this study interest would be based on the uniform model prior defined as:

$$P(M_j) = \left(\frac{1}{2^k}\right), \quad P(M_j) > 0 : \sum_{j=1}^{M} P(M_j) = 1$$

- Parameter Prior

The parameter prior with g-structure will be used in this study and its nature is Unit Information Prior (UIP) alongside the EBL and Hyper g-Priors using the MCMC Bayesian Model Sampling techniques (which include enumerate and birth-death sampling scheme).

Zellner (1986) introduced the concept of Unit Information Prior with the underlying assumptions of prior's covariance being proportional to the covariance matric structure defined as $(X_j^{*\prime} X_j^*)^{-1}$ of the posterior determined from the data with the scalar g (As depicted by the researcher or based on researcher's choice).

On the basis of rule of thumbs, since the g-structure would lead to simple closed form, we have the intercept as $P(\beta_0) = 1$, alongside the prior probability for precision $P(h) = \left(\frac{1}{h}\right)$. Hence the parameter prior becomes $P(\beta_j|h) \sim N(0_k, h^{-1}[g_j X_j^{*\prime} X_j^*])$ (Zellner, 1986). The mean deviation of X_j is given by X_j^* and the g-prior is noticeable to become smaller as there exist fewer prior parameter variance and it is proportional to comparable data.

According to Frogoso and Neto (2015), the application of Bayesian Model Averaging is essentially applied across a wide range of space. The derivation of posterior model probabilities in the BMA framework has given it a straightforward model choice approach since they become easily interpretable. The model space also has the tendency of being as wide as possible with not requirement for

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bookkeeping as regards the number of parameters or form of penalty as required by information criteria technique in the statistical literature.

Via the utility of BMA, one can come up with the estimates averaged over all considered models which can have a lower overall risk and take model uncertainty into consideration

III. RESULTS AND DISCUSSION OF FINDINGS

Table 2(a): Descriptive Statistics

	Consumption	Exchange	GDP	Food	Inflation	Trade	Unemployment
Mean	1.25E+12	316.0316	8.36E+10	100.9057	11.32685	67.99312	11.42541
Median	5.21E+11	87.12056	3.52E+10	100.6068	4.794918	62.65142	9.243500
Maximum	1.21E+13	2297.764	5.18E+11	181.5100	557.2018	149.8899	33.55900
Minimum	2.31E+09	1.407783	1.48E+09	68.91000	-2.430968	0.756876	1.078000
Std. Dev.	2.05E+12	479.4740	1.23E+11	11.75352	43.59646	29.73308	7.896433
Skewness	2.839678	2.296110	2.070922	1.752620	9.770537	0.344977	0.582448
Kurtosis	11.97162	8.601719	6.238798	12.90020	108.2329	3.073706	2.069091
Normality Test							
Jarque-Bera	1352.942	629.6129	331.7362	1323.608	137469.9	5.777645	26.68286
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.055642	0.000002
N	288	288	288	288	288	288	288

Table 2(b): Descriptive Statistics by Region

Region		Inflation	Exchange Rate	Unemployment	GDP (10^{10})	Food Production	Government Consumption (10^{12})	Trade Openness
Central Africa	Mean	6.01	622.59	9.13	3.00	98.40	1.12	74.50
	Std. Dev.	7.19	398.88	6.22	2.71	7.09	7.12	23.50
Eastern Africa	Mean	23.82	717.98	3.11	3.73	103.28	2.79	47.67
	Std. Dev.	87.52	790.11	1.55	2.63	9.98	3.82	13.02
North Africa	Mean	18.66	27.46	12.99	14.90	100.28	0.80	56.39
	Std. Dev.	52.66	39.02	3.44	10.88	9.38	1.36	30.50
Southern Africa	Mean	5.06	11.43	23.35	7.45	102.37	0.18	94.34
	Std. Dev.	1.51	2.99	3.03	13.49	7.94	0.33	28.42
West Africa	Mean	5.59	281.09	6.88	11.80	19.43	1.70	25.06
	Std. Dev.	5.74	230.38	3.43	17.95	19.43	1.70	25.06
Total	Mean	11.33	316.03	11.43	8.36	100.91	1.25	67.99
	Std. Dev.	43.60	479.47	7.90	12.32	11.75	2.05	29.73

Table 1(a) and 1(b) show the average GDP, inflation rate, exchange rate, unemployment rate, food production, government consumption and trade openness. The variability in the variables is accounted for by the standard deviation.

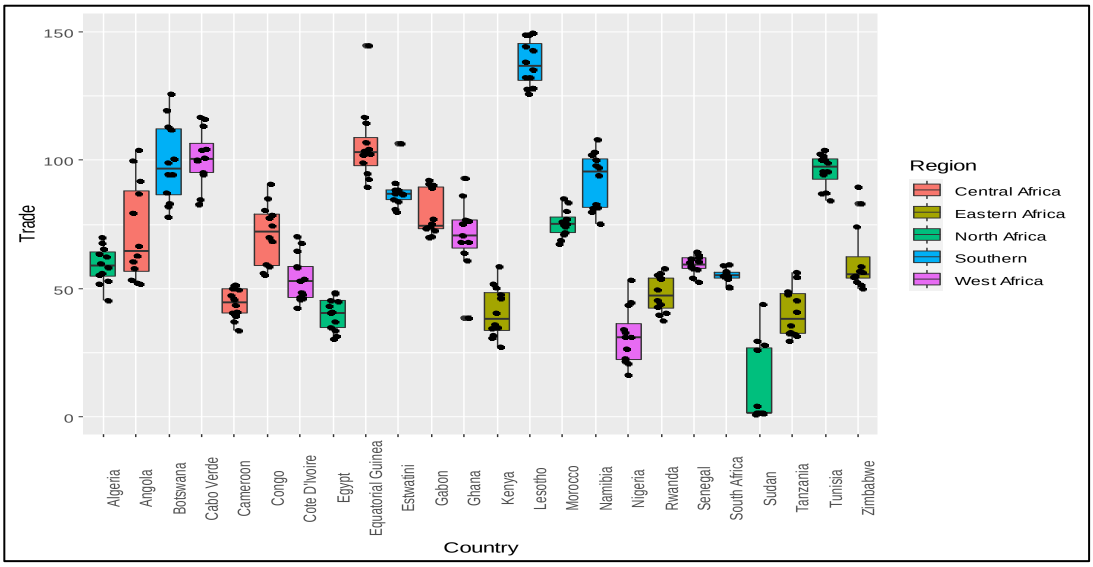


Fig. 1: Boxplot for Trade Openness

Figure 1 indicates that Lesotho in the Southern Africa region has an increasing trade openness among the observed countries followed by Equatorial Guinea in the Central Africa region. It is discovered that countries in the Southern region are more opened to trade as compared to others.

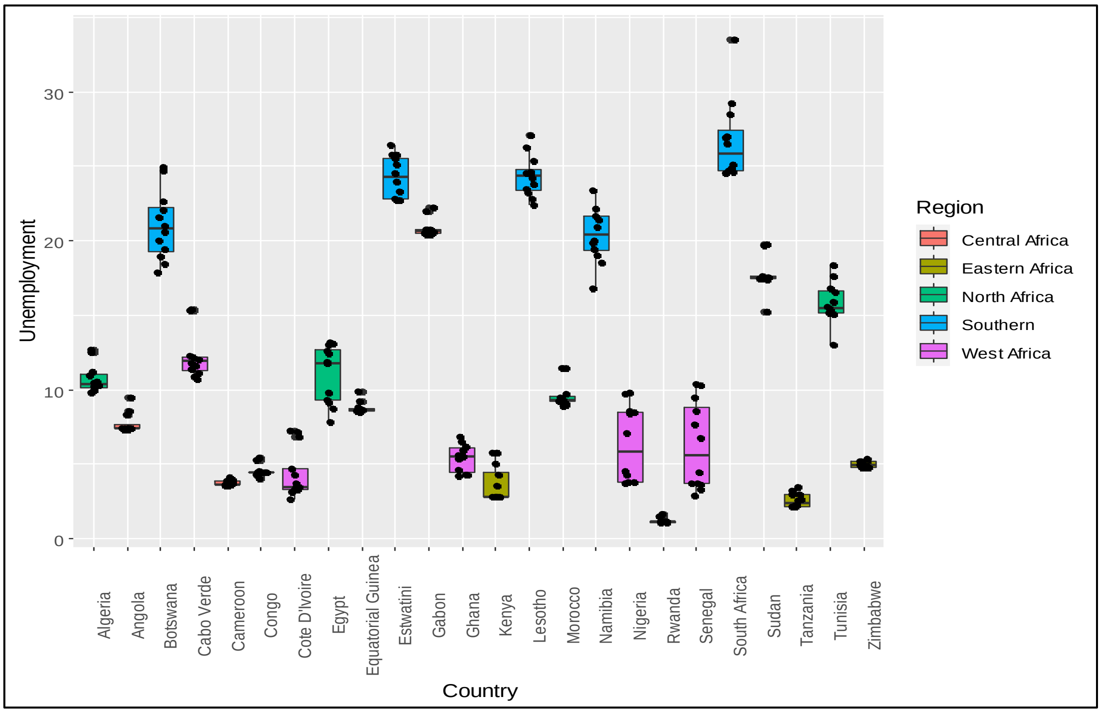


Fig. 2: Unemployment Rate

The unemployment rate is presented in figure 2 with the highest rate attributed to the Southern region in Africa. Lowest rate of unemployment is found for countries in the Eastern region (Rwanda being the least) followed by Western Africa. South Africa is identified as the leading country in Africa among the observed countries in the study.

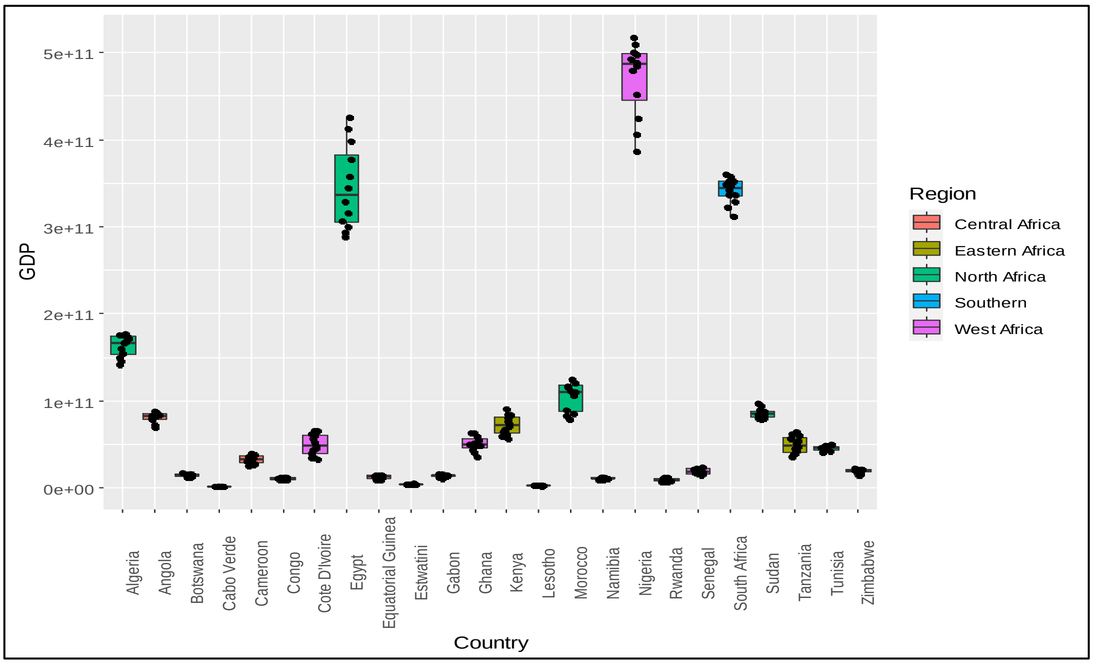


Fig. 3: Gross Domestic Product

Figure 3 gives the boxplot visual display of the gross domestic product with Nigeria being the leading countries and located in West Africa followed by South Africa in the Southern region and Egypt, Algeria and Morrocco in the North Africa region whereas, Cote D'Ivoire, Eswatini and Lesotho have very low gross domestic product.

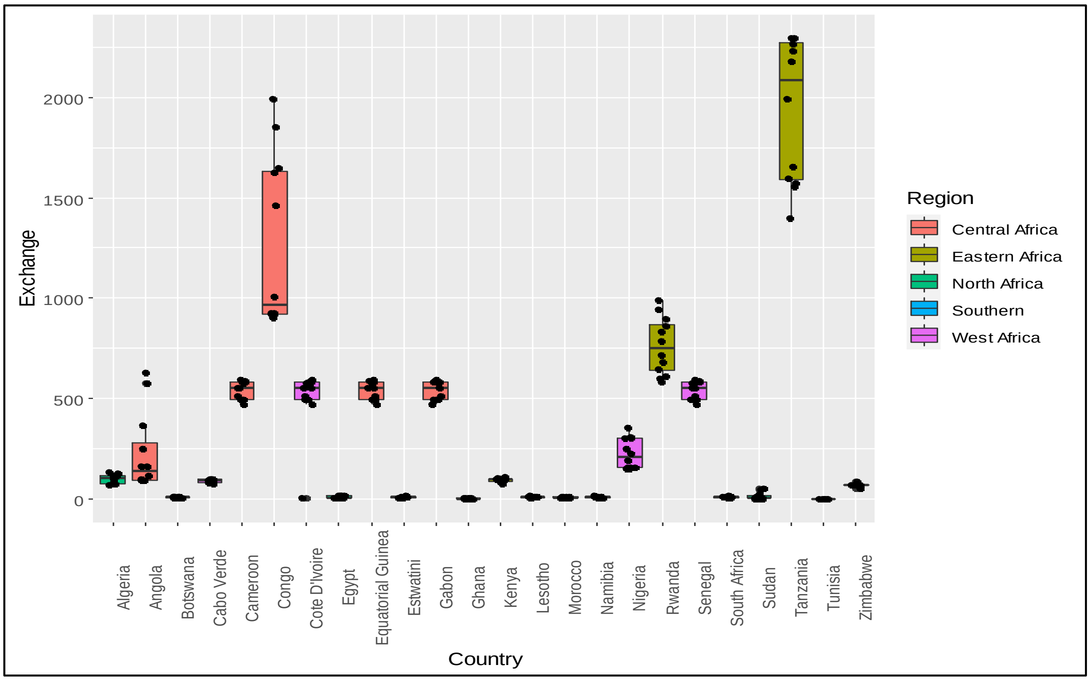


Fig. 4: Exchange Rate

The exchange rate for the countries – region wise is presented in figure 4 using boxplot. Tanzania in the Eastern Africa has highest exchange rate followed by Congo in the Central Africa then Rwanda in the Eastern Africa region. Cameroon, Equatorial Guinea, Gabon (in the Central Africa) and Cote D'Ivoire & Senegal (in West Africa) maintains some levels of status-quo in exchange rate while Botswana, Egypt, Eswatini, Ghana. Lesotho, Morocco, Namibia, South Africa, and Tunisia have very low exchange rate suggesting that low exchange rate is more associated with countries in the Southern and North Africa regions.

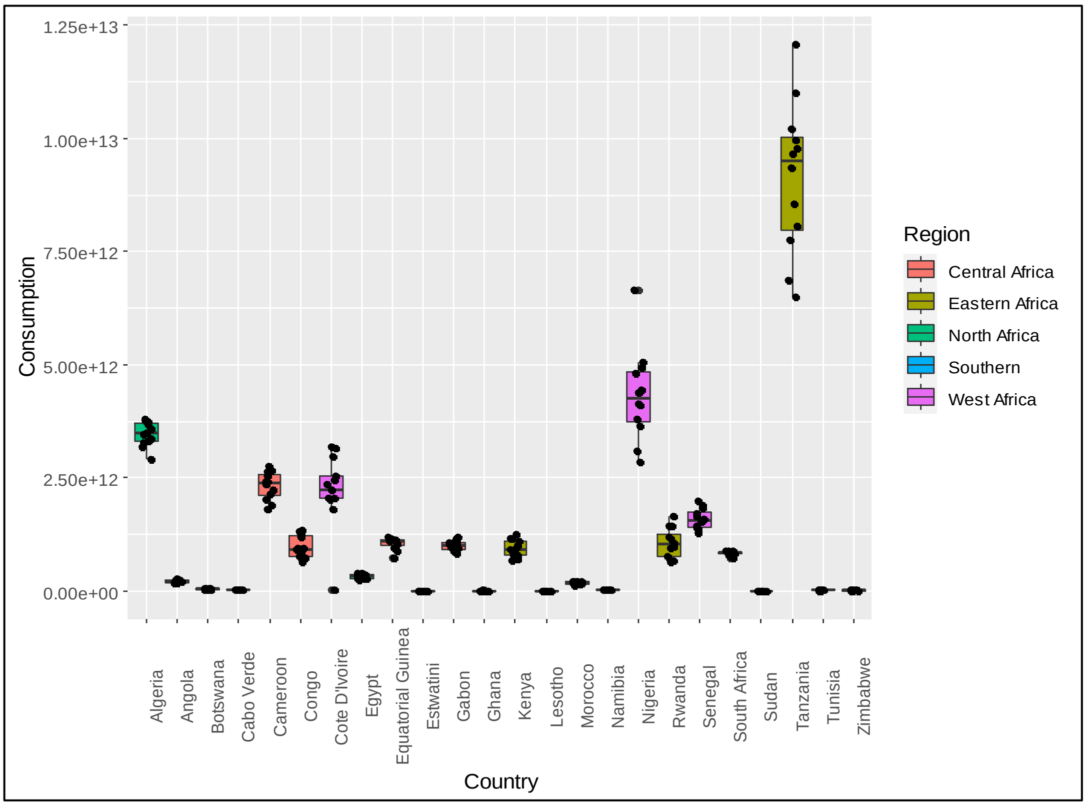


Fig. 5: Government consumption

Figure 5 shows the boxplot of Government consumption for all the observed countries. Highest government consumption is found for Tanzania followed by Nigeria then Algeria. All countries in the Southern Africa maintains a relatively low government consumption.

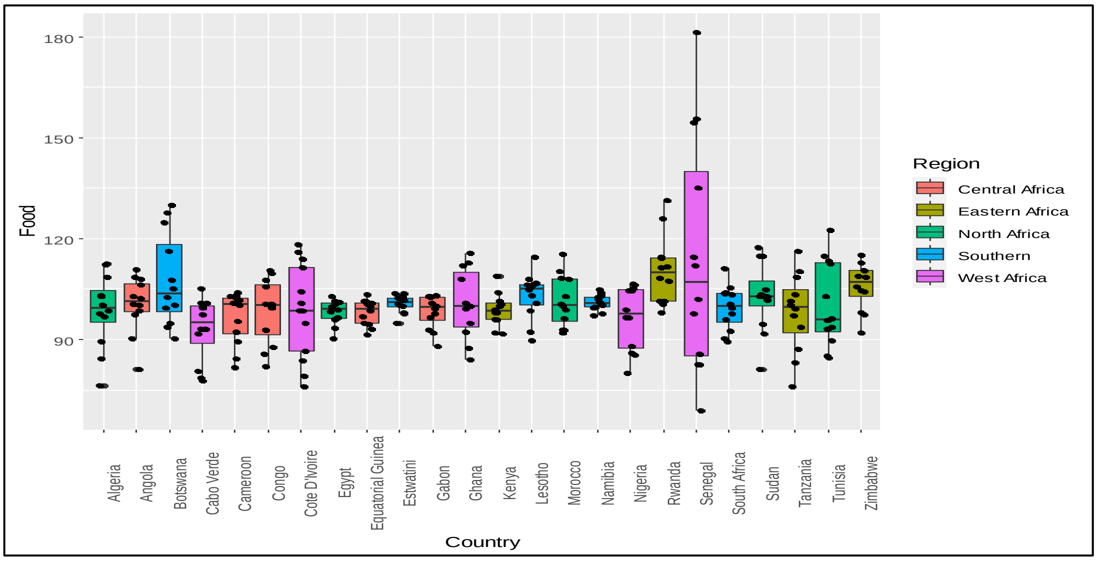
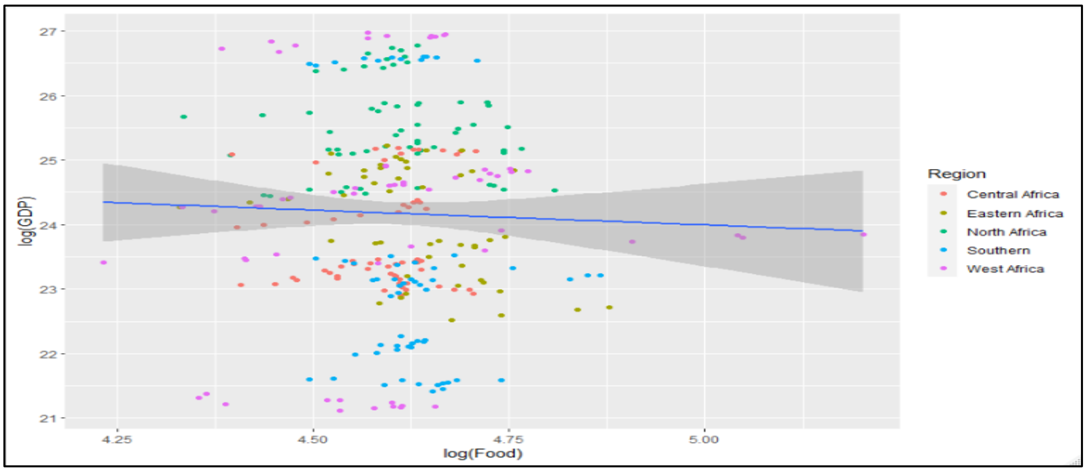
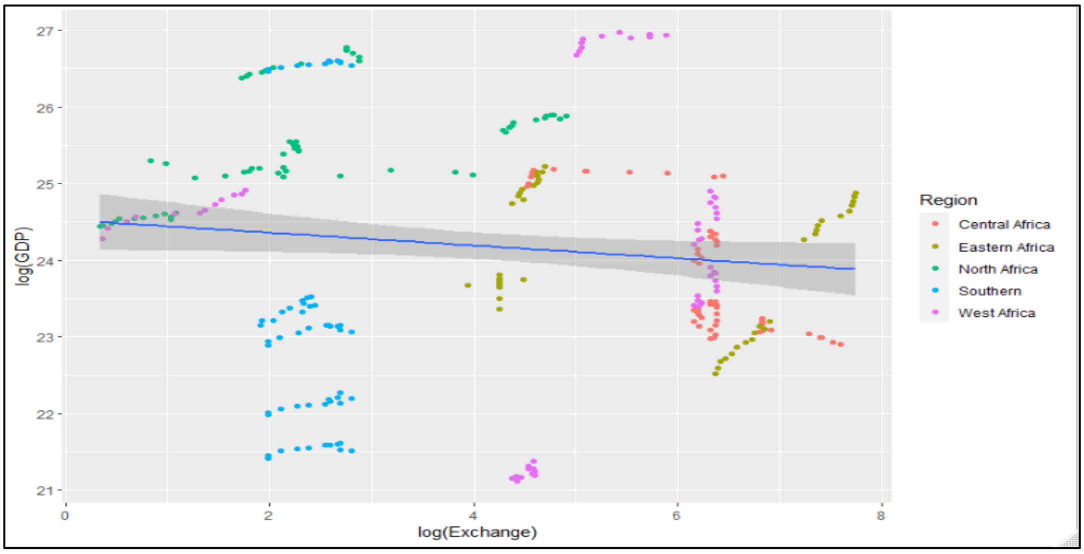


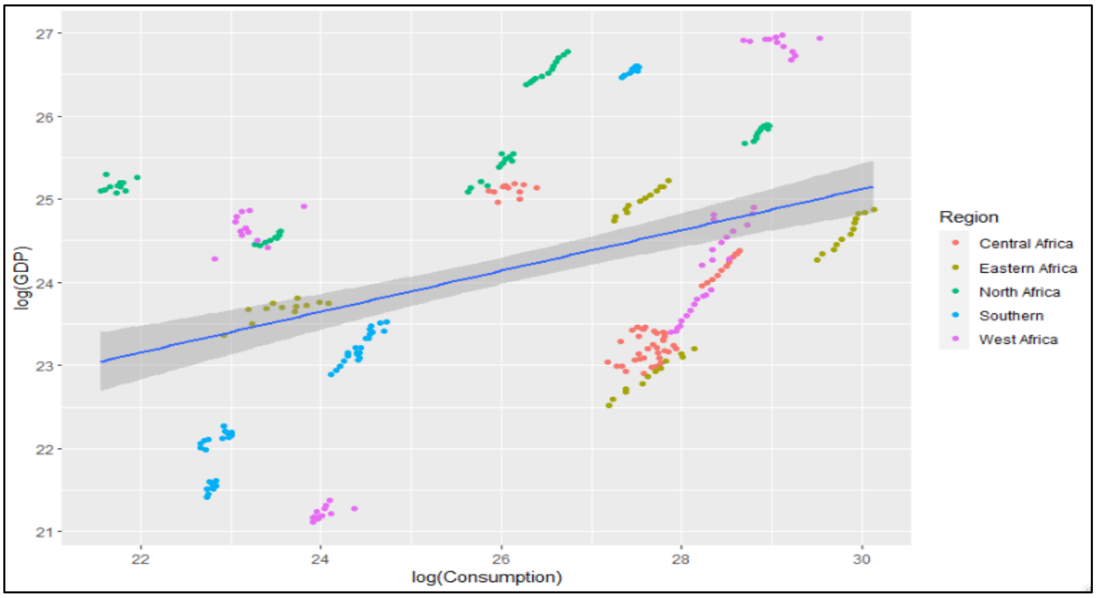
Fig. 6: Food Production

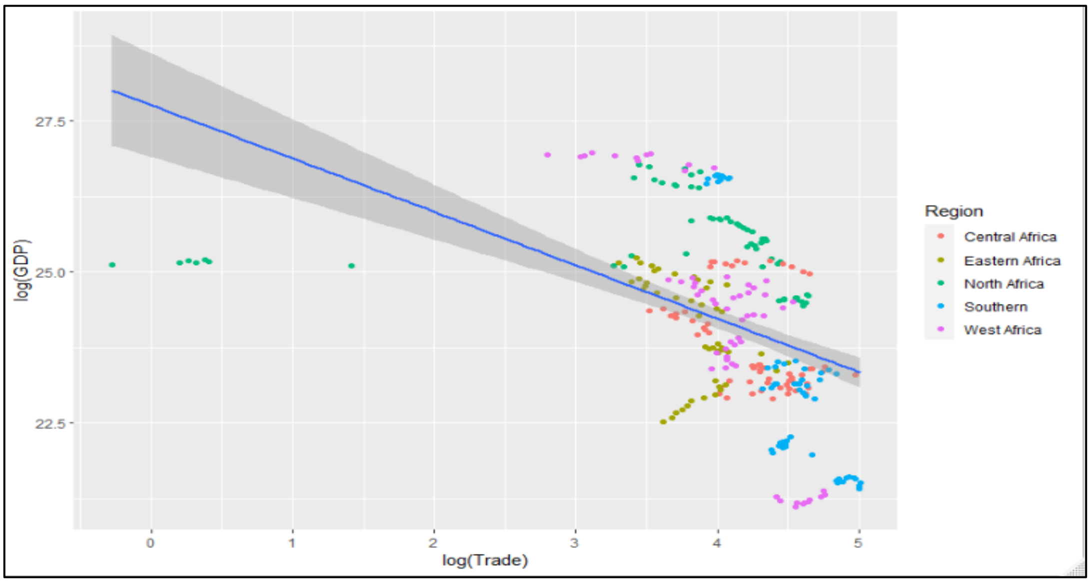
The level of food production is closely related among the countries as portrayed figure 6.Much variability is traceable to Senegal having a very high outcome/low at some points in time in comparison with others followed by Cote D'Ivoire, Botswana and Tunisia. It is also observed that Central Africa countries have relatively similar median food production over the time of study.

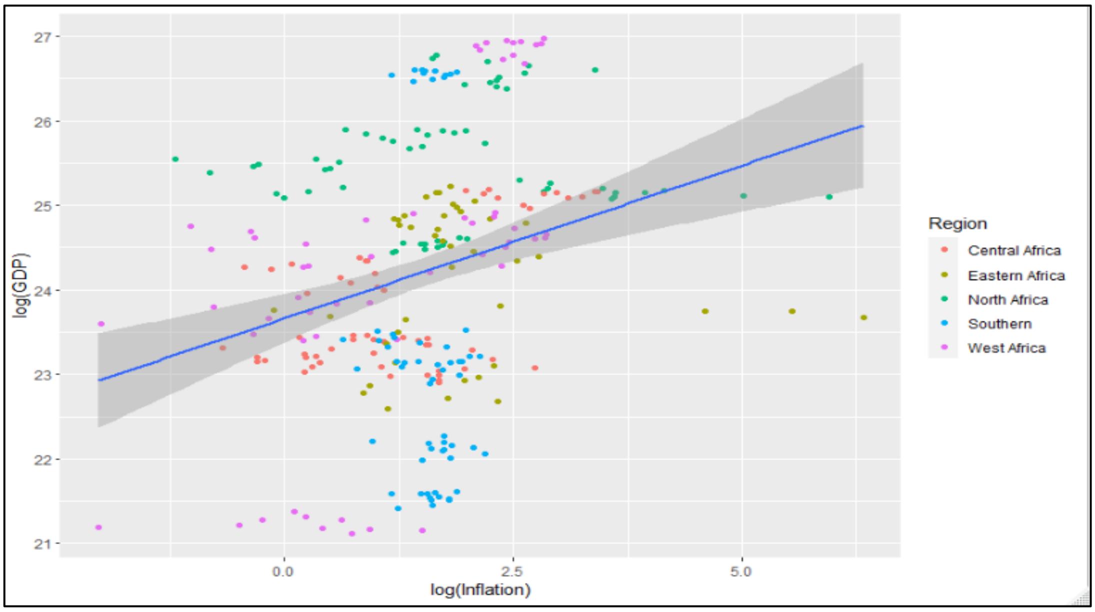
A. *Estimated Linear Relationship Plots*






log(GDP)
27
26
25
24
23
22
21
22
24
26
28
30
log(Consumption)
Region
Central Africa
Eastern Africa
North Africa
Southern
West Africa


log(GDP)
27.5
25.0
22.5
0
1
2
3
4
5
log(Trade)
Region
Central Africa
Eastern Africa
North Africa
Southern
West Africa


log(GDP)
27
26
25
24
23
22
21
0.0
2.5
5.0
log(Inflation)
Region
Central Africa
Eastern Africa
North Africa
Southern
West Africa

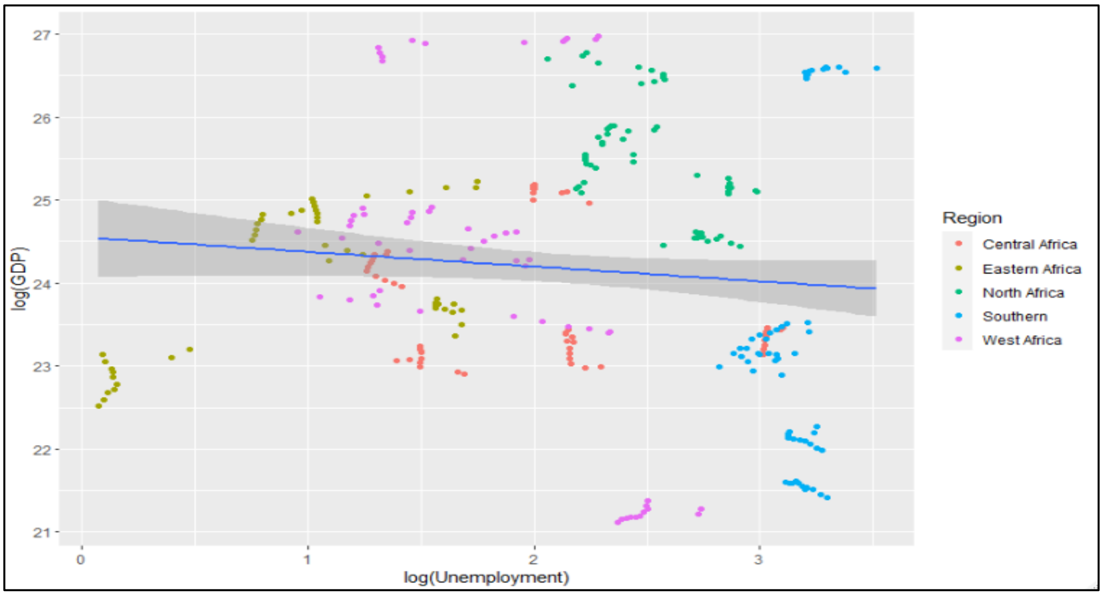


Fig. 7: Estimated linear relationship plots

The sample linear relationship is visualized in figure 7 to identify the inherent form of relationship between gross domestic product and its determinants. Plots show that unemployment, trade openness, exchange rate and food production have negative inherent impact while inflation rate and government consumption impose a positive impact in Africa.

Table 3: Panel Unit Root

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-1.50182	0.0666	7	1981
Breitung t-stat	-3.00847	0.0013	7	1974
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-7.55093	0.0000	7	1981
ADF - Fisher Chi-square	109.814	0.0000	7	1981
PP - Fisher Chi-square	134.963	0.0000	7	2009

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Table 2 accounts for the state of stationarity possessed by the underlying economic variables. Results show that the variables possess common unit roots, hence they are co-integrated.

Table 4: Long-Run Covariance

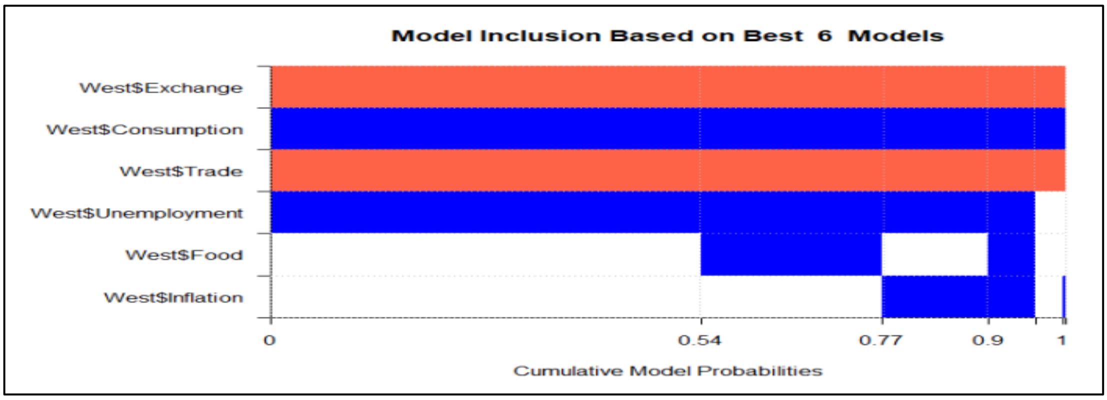
Variable	GDP	Government Consumption	Exchange Rate	Food Production	Inflation Rate	Trade Openness	Unemployment
GDP	7.66×10^{22}	2.44×10^{23}	-7.23×10^{13}	-7.35×10^{11}	1.86×10^{12}	-8.48×10^{12}	1.08×10^{11}
Government Consumption	2.44×10^{23}	2.03×10^{25}	3.60×10^{15}	-7.34×10^{12}	-1.65×10^{13}	-1.25×10^{14}	
Exchange Rate	-7.23×10^{13}	3.6×10^{15}	1.2×10^{6}	467.62	-9857.53		
Food Production	-7.35×10^{11}	-7.34×10^{12}	467.62	325.88			
Inflation Rate	1.86×10^{12}	-1.65×10^{13}	-9857.53				
Trade Openness	-8.48×10^{12}	-1.25×10^{14}					
Unemployment Rate	1.08×10^{11}						

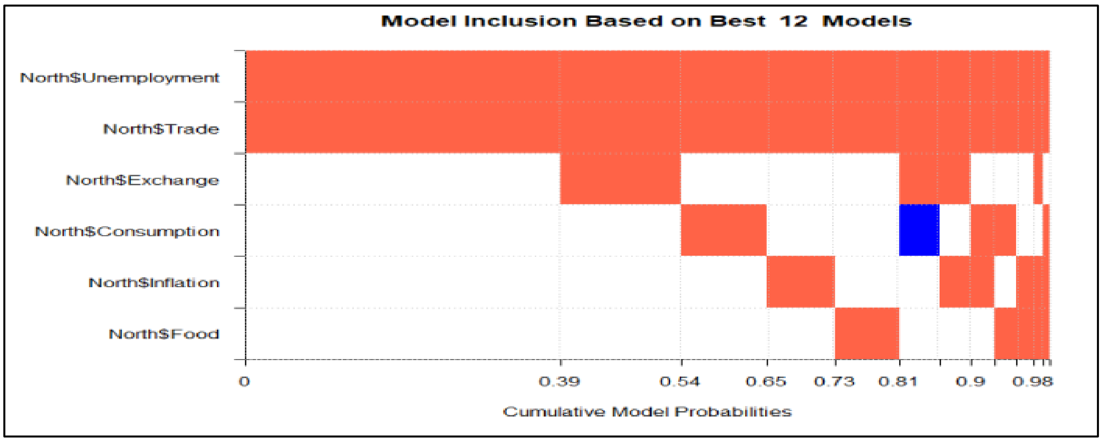
The long-run covariances between the economic variables are presented in table 3. It is discovered that government consumption, inflation rate and unemployment have long run positive impact on GDP in Africa while exchange rate, food production and trade openness pose negative impact on economic growth in Africa.

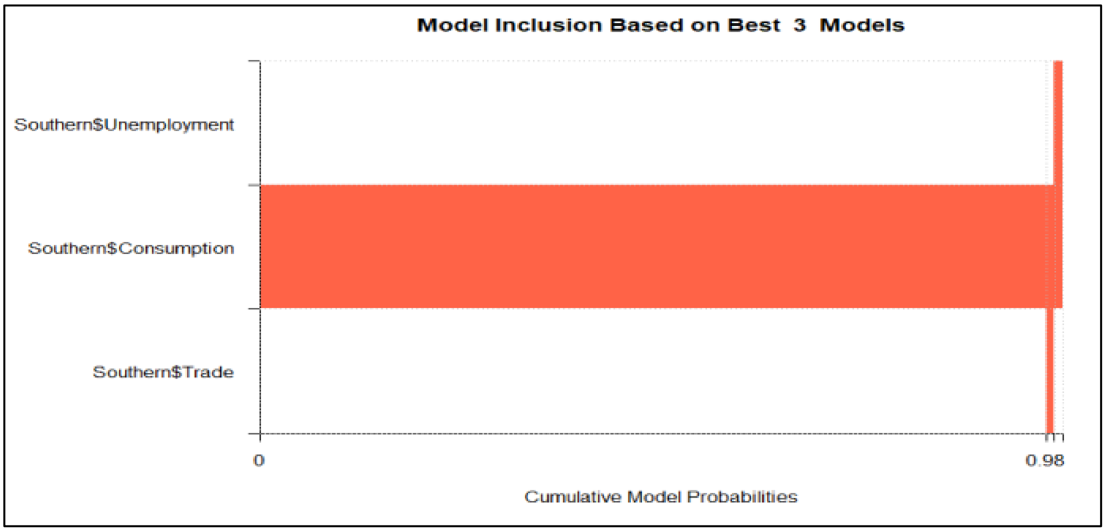
The formal data analysis underlying the Bayesian Model Averaging is carried out considering two possible form of model prior namely "random" and "uniform". The two model prior forms were investigated in relation to three different possible gprior namely "UIP", "EBL" and "hyper" considering two different form of Bayesian Model Sampling techniques: "enumerate" and "bd = birth-death" MCMC approaches.

The infeasibility of the enumerate MCMC approach leads to the adoption of the birth-death MCMC with the strong capacity to model samples that would Posterior Model Probabilities under all possible conditions.

B. Variable Inclusion Plots







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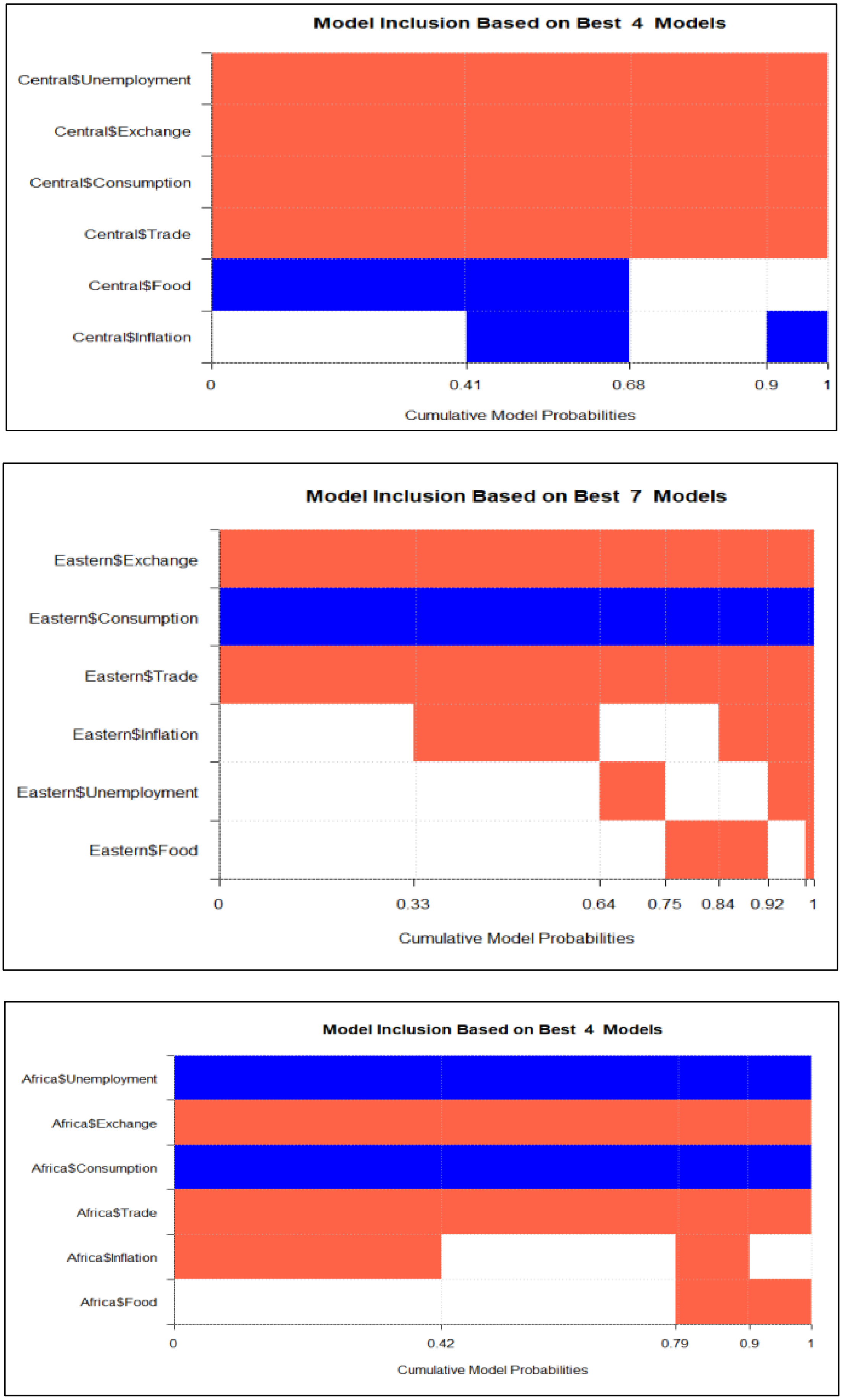

Fig. 8: Variable Inclusion Plots

Table 5: Dominant Bayesian Model Averaging (BMA) by Cross-sections

Cross-section	Model Prior: (Random/ Uniform)	g-Prior: (UIP/EBL/ Hyper)	Posterior Model Size	Posterior Model Probability (Corr.)	Variable Inclusion (*PIP* > 50%)
Southern Africa	Uniform	Hyper	1.02	1.0000	Government consumption (+*), Unemployment (+), and Trade openness (+).
Northern Africa	Uniform	Hyper	2.72	0.9764	Unemployment (-*), Trade openness (-*), Inflation rate (-), Food production (-), Government consumption (+)
Central Africa	Uniform	Hyper	4.97	0.9664	Unemployment (-*), Exchange rate (-*), Government consumption(-*), Trade Openness(-*), Food production (+*), and inflation rate (+)
Western Africa	Uniform	Hyper	4.36	0.9620	Exchange rate(-*), Government consumption(+*), Trade openness(-*), Unemployment(+*), Food production (+), and Inflation rate(+)
Africa	Uniform	EBL	4.61	0.9748	Unemployment (+*) exchange Rate (-*), government consumption(+*), trade openness(-*), Inflation rate (-) and Food production (-).

∗ implies significant contribution of variable, − and + indicate negative and positive impacts respectively.

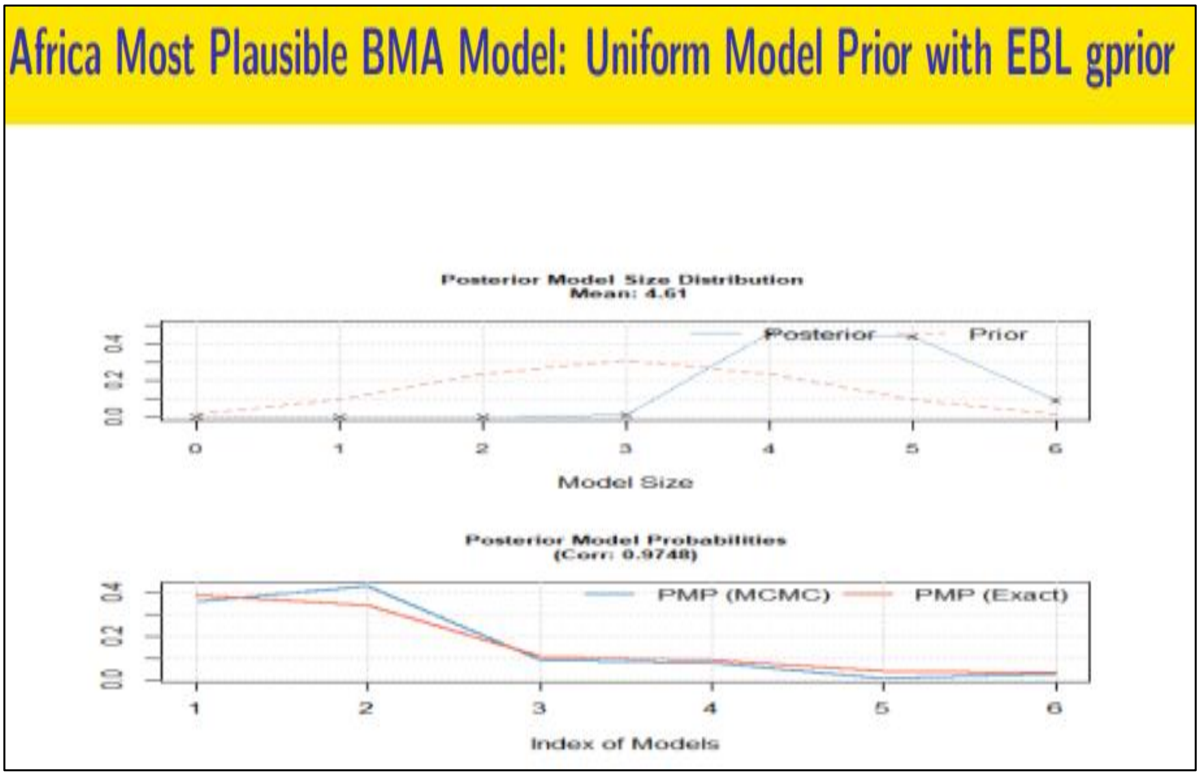

Fig. 9: Africa Most Plausible BMA Model with EBL gprior

Africa economic growth model underlying the EBL gprior shows that unemployment, exchange rate, government consumption and trade openness have a sure probability of inclusion into the model in the order of their posterior means from the highest to the lowest. Considering the conditional posterior sign, it is found that both unemployment and government consumption have significant positive impact on economic growth in Africa.

IV. CONCLUSION

Southern Africa has the highest average GDP with the least variation over the period of study. The tests of group unit root indicate that all the macro-economic variables are co-related. The most plausible BMA model for Africa is identified to be Uniform model prior with EBL gprior Bayesian Model Scheme. In the Southern Africa region, only government consumption is identified as the variable with great impact on economic growth. Among the other region, unemployment is found to be only one of the leading determinants of economic growth. Considering the entire model, BMA with hyper gprior associated with uniform model prior is most plausible in the modelling of economic growth in Africa subregions.

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