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Inflation in Sub-Saharan Africa: A Markov-Switching Regression Approach

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Abstract
With a view to identifying countries with greater inflation challenges and making appropriate recommendations, this paper modeled inflation ratesin sub-Saharan Africa (SSA). 30 countries, including the 3 which have earlier experienced hyperinflation, were selected to be studied between 1960-2019. The Markov-switching (MS) model was employed to segment inflation rates into different states of stable, high and hyper-inflation.MS results identified Ethiopia, Angola and Seychelles as ones with greater challenges compared to Burundi, Gambia, Madagascar, Malawi, Tanzania, Ghana, Kenya, Nigeria, Zambia and Botswana. Results also showed that volatility in SSA increases with increasing inflation rates, the hyperinflation being the most volatile state. In addition, results were also used to investigate similarities in inflation patterns. This was with a view to assessing the readiness of Africa to establish proposed monetary unions. Similarity indices revealed that Togo, Burkina Faso, Guinea-Bissau, Mali, Niger, Cabo Verde, Cote d'Ivoire and Senegal met the single-digit criterion in the period under review. This is a clear indication that EAC and ECOWAS regional communities have made significant progress in achieving inflation convergence, and with consistent effort, EAC should be able to institute a monetary union in 2024.

Key Words: Nonlinear regression, Monetary union, Income groups, Volatility, Friedman's hypothesis

JEL Codes: C01, C12, C13, C58, E31

1. Introduction

What is inflation? It is the persistent rise in the general price level of services and goods in a geographical location (country, region, etc.) over a long period of time. Inflation rates remain one of the key macroeconomic variables globally and also a major topic of interest to researchers due to the fact that it directly affects the standard of living. Over the years, economic institutions such as the World Bank and the International Monetary Fund (IMF) have proposed several intervention programs to ensure price stability in Africa; these include the Economic Recovery Program (ERP) and the Structural Adjustment Program (SAP). Despite these interventions, it appears as if the desired outcome is still elusive. Hence the major objective of this paper is to model inflation in sub-Saharan Africa (SSA) in order to identify areas where more work needs to be done and also make appropriate inferences.

On the other hand, inflation modeling studies in sub-Saharan Africa (SSA) are mostly country-specific[1], very few ones have considered modeling regional inflation and its dynamics[2]. However, with the recent proposal of regional economic integration which is expected to culminate in the formation of various monetary unions, it becomes imperative to extend inflation studies beyond the national to the regional level. In addition to the stated objectives, result from this study will be used to investigate the similarity level in the inflation pattern among SSA countries as this is a necessary condition for a lasting union: differences in the cross-country inflation rates could make policy development and implementation very difficult

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[1] See for instance Okorie et al. (2019).
[2] See London (1989), Fielding, Lee, and Shields (2005), Nguyen et al. (2017) and Banerjee (2017).

(Rogers, 2001). Itwill also be usedto identify countries which have made relatively significant progress in achieving single-digit inflation rates and those requiring urgent attention and intervention. All these cannot be achieved in *isolated* studies.

Modeling inflation in SSA could be a difficult task considering various structural changes to inflation dynamics that could arise from different policy directions in the different countries. Stuctural changes could also be due to continuous modifications in exchange rates policies and regimes in these countries. Certainly the various forms of linear specification usually adopted in previous studies cannot capture these nonlinearities. On the other hand, Friedmann (1977) posited that periods of higher inflation are usually accompanied by high volatilities. Linear model residuals are structurally assumed to be homoscedastic, thus making it difficult to model inflation dynamics appropriately.

The Markov switching model (MSM) of Hamilton (1989), in contrast, endogenously captures structural breaks and allows varying variances. Markov-switching regression models employ very simple equations while allowing for discrete *regime shifts* in its generating process. It is a mixture of the Markov and autoregressive processes in the manner that allows the mean inflation rates to switch between two (or more) unobserved states in a stochastic fashion. Thus inflation rates can be segregated into $k > 1(k \in N)$ distinct states such that its governing process shifts between these k states in a probabilistic fashion. For instance, inflation rates in SSA may be segregated into stable and high states. Once the high inflation episodes are identified, it is then possible to isolate countries with high inflation challenges. It is also possible to measure the level of inflation convergence among countries in the two states of stable and high inflations.

The rest of the paper is organized as follows: Section 2 presents the data and gives brief review of inflationary trends in sub-Saharan Africa, Section 3 describes the method used; Setion 4 presents and discusses the empirical results while the last section contains the conclusion and some recommendations.

2. Data Presentation and Brief Review of InflationaryTrends in Sub-Saharan Africa

For detailed description of the inflationary process and to be able to compare results, we discuss the inflation trends in SSA by income groups.

The World Bank classified 48 out of 54 African countries as sub-Saharan. Though the data spans 1960 to 2019, we selected countries which have complete data for at least 1989–2017, that is, at least a minimum of 30 observations, in order to accommodate more countries and at the same time have a handful of datasets to work with for each selected country. The selection of 1989 and 2017 is strategic, as we intend to compare inflation pattern for SSA by country in the old and recent times in the course of the study. 27 countries fit this criterion and were therefore selected. We note that our selection captures all the inflation patterns in SSA from 1960- 2019, that is, the low, moderate and high except for the hyperinflation, as the three countries which experienced hyperinflation between 1960 and 2019 in SSA, namely, Angola, Congo DR and Zimbabwe, did not satisfy the criterion. Therefore, for a comprehensive modeling and description of SSA inflation pattern, we analyzed the 3 countries together, but separate from the 27 selected countries earlier selected so that their outlying observations would not distort the overall result. Thus a totalof 30 countries were selected and categorized into the following 4 groups: Low income, Lower-middle income, Upper-middle and High income[3], and the Hyperinflation. Data on inflation rates were obtained from the World Development Indicators Website. See Appendix for a list of selected countries together with their corresponding income groups, the start and end years of their datasets.

Figures 1-4 displayed the plots of selected SSA countries. It is obvious from the plots that some of the countries in the Low and Lower-middle income (see Figures 1 and 2) categories

[3] The High income group has only one member (Seychelles), it is therefore joined to the Upper-middle group.

have seen marked improvement in the inflation rates between 2004 and 2019; these include Cote d'Ivoire, Burkina Faso, Cameroon, Gambia, Guinea-Bissau, Mali, Mauritania, Niger, Senegal, Eswatini and Togo. It is also noteworthy that Zambia has significantly recovered from the 1993 experience. However, the rest of the countries in the two groups still have their inflation rates much greater than 10%: showing that a lot needs to be done to bring inflation rates to the desired single digit. The Upper-middle and High[4]income group, in contrast, has shown some considerable improvement.It can be seen that Gabon, Mauritius and Equatorial Guinea experienced some pronounced spikes of inflation in the nineties; however, prices appeared to be relatively stable afterwards. The same can be said for Botswana and Seychelles; after the spike seen in 2008, prices seemed to have become stable.Finally, Figure 4 showed that the hyperinflations experienced by Zimbabwe and Congo are much greater in magnitude than that of the Angola. It also showed that the inflation rates in all the countries appeared relatively stable post-2008; though Angola continued to fluctuate between low and high inflation zones after 2012.

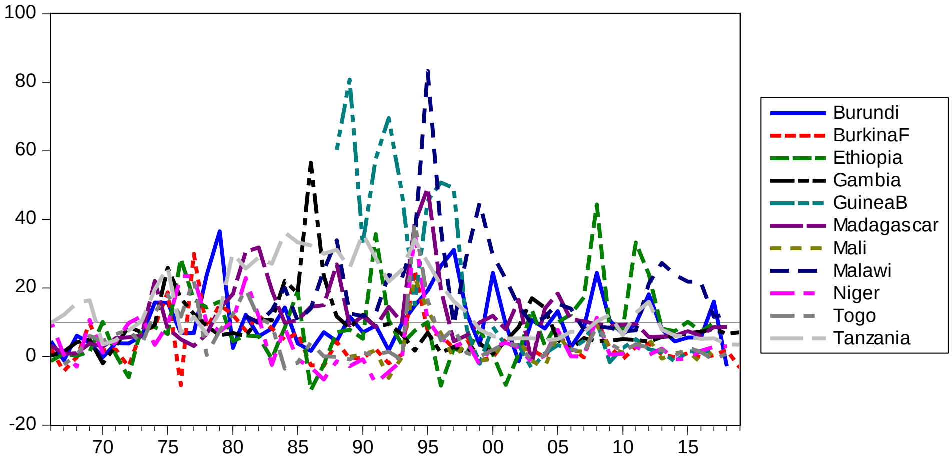

Figure 1: Inflation Rates for Selected Low Income countries in SSA (1960 – 2019)

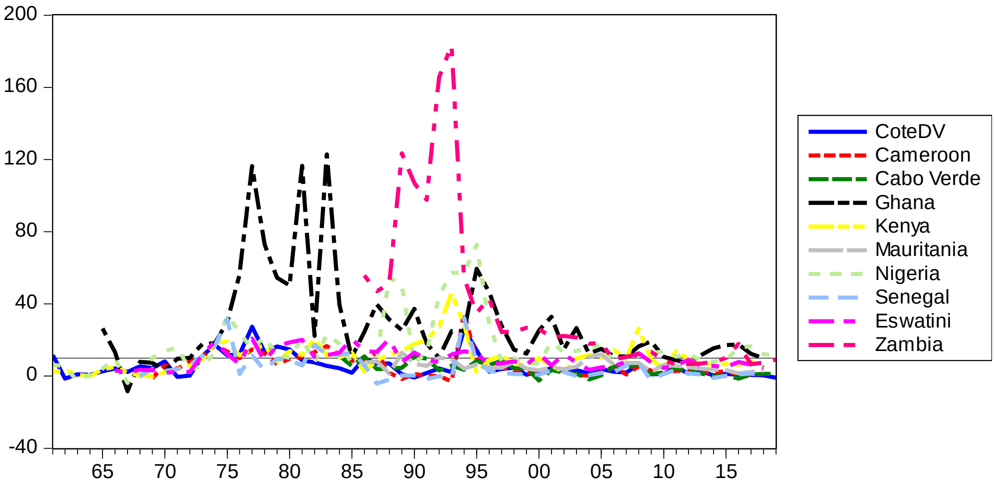

Figure 2: Inflation Rates for Selected Lower-Middle Income Countries in SSA, 1960 – 2019.

[4] Only one country, Seychelles falls in the high income group. Its graph is therefore presented with those of the Upper-middle income group.

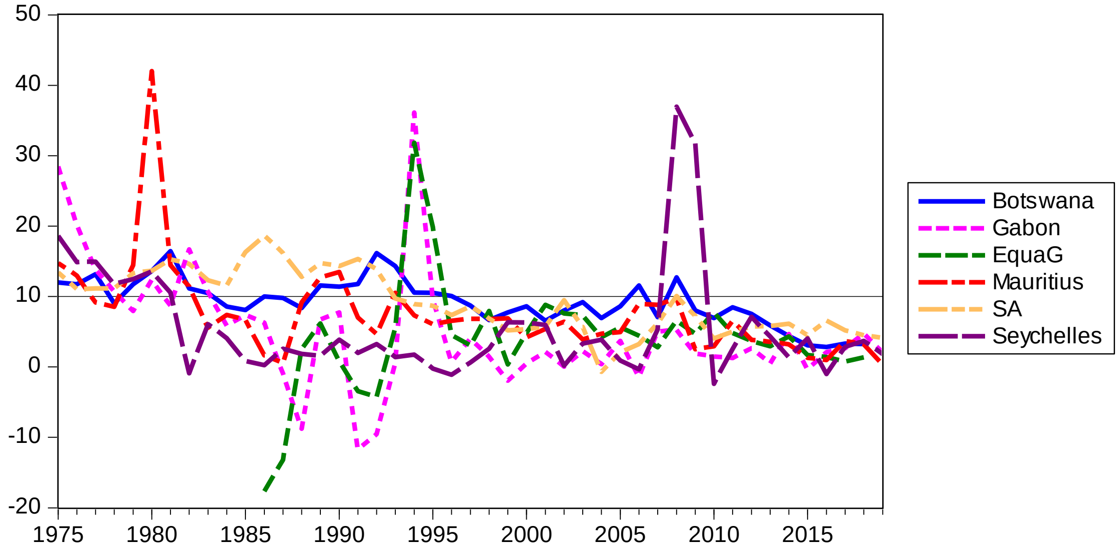

Figure 3: Inflation Rates for Selected Upper-Middle and High Income Countries in SSA (1960 – 2019)

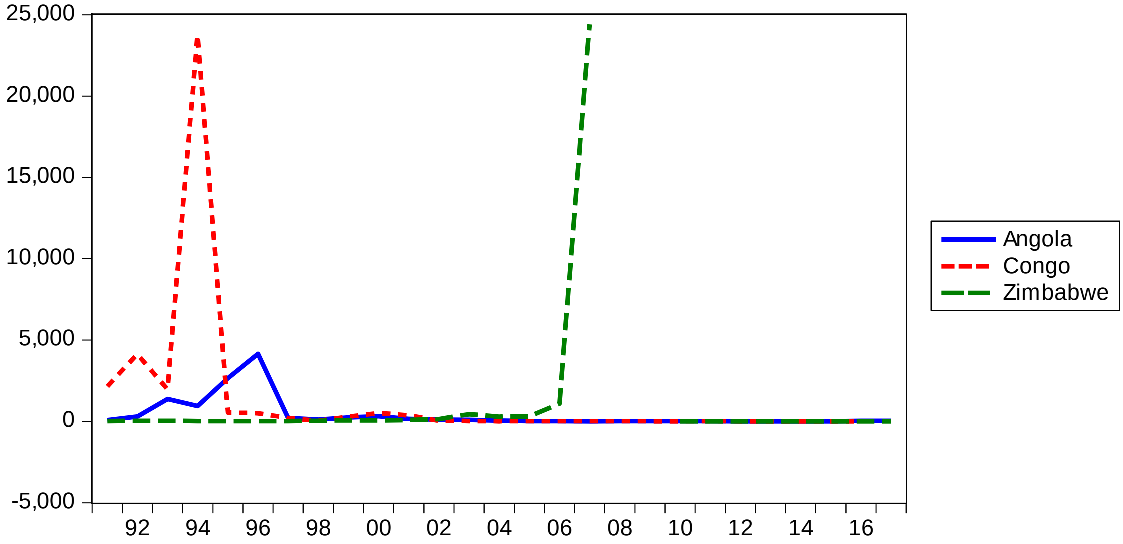

Figure 4: Inflation Rates for All Countries with Hyperinflations in SSA (1960 – 2019)

2.1 Unit Root Tests for Stationarity

Each of the 4 groupswere tested for the presence of unit root using the Levin, Lin and Chu (2002) procedure which assumes common unit root and also the Im, Pesaran and Chin (2003) and the Fisher-type tests which both assume individual unit root process. Panel test results, presented in the Appendix showed that the series are all stationary.

3. The Markov-switching ANCOVA Model

Our major objective is to model inflation dynamics in SSA in order toidentify countries with high inflation challenges and make appropriate recommendations. In line with Gujarati and Sangeetha (2004), we assumed that changes in inflation are not instantaneous such that they can be predicted by past inflation. In addition, in line with our major objective and also following Franses and Janssens (2018) which earlier established that African countries have both common and specific inflation features, we include dummy variables in our model to account for country-specific variations. These simplifying assumptions allow one to model inflation patterns and also measure the impact of each selected country on aggregate inflation rates in each of the 4 groups.

We note in passing that by excluding standard predictor variables, our modeling approach clearly ignores information contained in them. Nonetheless, this approach may be relevant to identifying inflation challenges in the individual countries relative to the overall SSA inflation. Undoubtedly, this approach is appropriate for building inflation model for policy and intervention analysis (especially for standard economic organizations like IMF and World Bank who make policies and interventions for regions and individual countries alike). In addition, similar applications usually also do not include explanatory variables. See for instance, Hamilton (1989, 1990), Evans and Wachtel (1993), Laxton, Ricketts and Rose (1994) and Ricketts and Rose (1995). It is also known that the ability of the Markov-switching model to capture structural breaks and inflation fluctuation endogenously most certainly increases its goodness-of-fit for historical data.

Consider the following ANCOVA model:

$$INF_t = \sum_{k=1}^{p1} \alpha_k INF_{t-k} + \sum_{j=1}^{p2} \mu_j D_{jt} + \varepsilon_t,\ t = 1,2,\cdots,T; \quad \varepsilon_t \sim N\left(0,\sigma^2\right) \quad (1)$$

where *INF* are the inflation rates and $\alpha's$ are the coefficients of their lag terms so that $p1$ represents the number of lag terms included in the model, *D*'s are the dummy variables included in Equation (1) to measure the each country's relative contributions to the overall inflation, $p2$ represents the number of countries considered for each group), the means μ are the coefficients of the dummy variables, σ^2 is the variance of the random error term ε, and *t* represents time so that *T* varies according to the start and end years displayed in the Appendix.

Note that the intercept term is not included in Equation (1). This is to ensure that the individual contributions of each of the countries to the inflation patterns are easily identified. Dummy variables for each group's model were created as follows:

$$D_i = \begin{cases} 1, & if \text{ inflation rates belongs to country } i\ \left(i \in \mathrm{N}\right) \\ 0, & otherwise \end{cases}. \quad (2)$$

Thus 11 dummy variables were created for the Low income group model, 10 for the Lower-middle group model, 6 for the Upper-middle and High group's model, while 3 were created for the Hyperinflation group.

In addition, the number of lag terms $p1$ to be included in each model is informed by the correlogram. We note that inclusion of lag terms of the inflation rates also helps to correct for serial correlation.

Now, in the Low income group, for instance, there are 11 countries. Thus Equation (1) adapted for the Low income group is

$$INF_t = \sum_{k=1}^{p1} \alpha_k INF_{t-k} + \sum_{j=1}^{10} \mu_j D_{jt} + \varepsilon_t,\ t = 1,2,\cdots,T; \quad \varepsilon_t \sim N\left(0,\sigma^2\right) \quad (1a)$$

Hence Equation (1a) is an unbalanced panel ANCOVA model.

A typical Markov-switching autoregressive model is written as

$$\left.\begin{array}{l} INF_t = \mu_{S_t} + \varepsilon_t \\ \quad \varepsilon_t \sim i.i.d\ N\left(0, \sigma_{s_t}^2\right) \\ \quad S_t = 1,2,\cdots,m;\ t = 1,2,\cdots,T \end{array}\right\} \tag{3}$$

where μ is the mean, σ^2 is the variance and t is the time (usually in months, quarters or years). The mean and the variance take *m* different values, each value representing the distribution pattern in the *m* different states.

A mixture of Equation (1) with System (3), assuming *2* states (i.e.*m* = *2*) gives the following panel Markov-switching ANCOVA model.

$$\left.\begin{array}{l} INF_t = \sum_{k=1}^{p1} \alpha_{k,S_t} INF_{t-k} + \sum_{j=1}^{p2} \mu_{j,S_t} D_{jt} + \varepsilon_t \\ \quad \varepsilon_t \sim i.i.d\ N\left(0, \sigma_{s_t}^2\right) \\ \quad S_t = 1,2;\ \ t = 1,2,\cdots,T, \end{array}\right\} \tag{4}$$

where mean $\mu's$ are the coefficients of the dummy variables in the *2* states and σ^2 is the variance in the *2* states. Each value of μ thus represent the average annual contribution of each country to the aggregate inflation in the *2* states while α are the coefficients of the lag terms, also in the *2* states.

All parameters depend on S_t, an unobservable discrete random variable which evolves according to the first order transition probabilities

$$P\left(S_t = 1 \middle| S_{t-1} = 1\right) = P_{11} = p, \tag{5}$$

$$P\left(S_t = 2 \middle| S_{t-1} = 1\right) = P_{12} = 1 - p, \tag{6}$$

$$P\left(S_t = 1 \middle| S_{t-1} = 2\right) = P_{21} = 1 - q \tag{7}$$

$$P\left(S_t = 2 \middle| S_{t-1} = 2\right) = P_{22} = q. \tag{8}$$

The fact that S_t is not directly observed prevents the conventional implementation of the maximum likelihood estimation method. Alternatively, Hamilton (1994) developed a process commonly referred to as "Hamilton's filter", which may be employed to obtain estimates for the model parameters.

One of the interesting features of the MS model is its ability to estimate the duration or persistence of an inflation state. This is computed as (Kim and Nelson, 1999),

$$E[D] = 1/\left(1 - P_{ii}\right), \tag{9}$$

where D is the duration of state $i(=1,2,\cdots,m)$. Moreover, filtered $\left(P\left(S_t = i \middle| \Phi_t\right)\right)$ and smoothing probabilities $\left(P\left(S_t = i \middle| \Phi_T\right)\right)$, where Φ_τ is the information available up to time τ, can be estimated as described in Kim and Nelson (1999). These probabilities attempt to reconstruct the inflationary behaviour observed in the original time series.

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4. Results and Discussion

This section presents and discusses the results.

4.1 Descriptive Analysis

Statistical analysis usually begins with data description. Table 1 refers to the summary statistics of the fourincome groups and the Hyperinflation group for the whole dataset (1960 – 2019) and a subsample (2004 – 2019)representing recent times.

Between 1960 and 2019, the lowest mean annual inflation rates was recorded by the Upper-middle and High income group, followed by the Low income group whose annual inflation rates averaged 9.4%. Average annual inflation rates for the Lower-middle income group stood at 12.3%. This relatively high value was, of course, due to the Ghanaian, Nigerian, and Zambian high inflation episodes of 1983, 1995, 1993, respectively. Sowa and Kwakye (1993) reported that the Ghanaian episode occurred due to narrow money supply growth from 1972 to 1982; the Nigerian 1995 experience was caused by poor monetary policy and pronounced reduction in the global oil prices; whereas Zambian high inflation episode was caused by large depreciation of the kwacha and indiscriminate money supply growth(Franses and Janssens, 2018). The Hyperinflation group had the highest mean annual inflation rates of whopping557.7%. This is a clear departure from the mean values of the other three groups.

Of all the four income groups, the Lower-middle was also the most volatile with 19.4% deviation followed by the Low income group with 11.9%.The Upper-middle and High income group was the least volatile with 6.9% deviation. Hyperinflation group has a standard deviation of 2984.2%. This indicates that the higher the inflation rates, the higher the volatility. It also holds that skewness and kurtosis increased with increasing inflation rates between 1960 and 2019.

In recent times, except for the Hyperinflation group, it appears that the average inflation rates in SSA have converged to <10%. Volatility has also reduced substantially in all the income groups except for the Hyperinflation group. A closer look at Figure 4 revealed that substantial improvement began in the Hyperinflation group in 2008. Accordingly, the annual mean inflation rates for 2008 – 2019 stood at 8.6%. Volatility also reduced substantially to 9%.

Table 1: Summary Statistics

	1960-2019				2004-2019			
Statistic	Low	Lower Middle	Upper Middle	Hyper	Low	Lower Middle	Upper Middle	Hyper
Mean	0.094	0.123	0.068	5.577	0.065	0.074	0.047	6.620
Maximum	0.833	1.833	0.420	244.110	0.444	0.435	0.370	244.110
Minimum	-0.098	-0.084	-0.176	-0.027	-0.032	-0.022	-0.024	-0.024
Std. Dev.	0.119	0.194	0.069	29.842	0.069	0.068	0.052	38.556
Skewness	2.288	4.669	1.340	7.490	2.007	1.717	3.964	6.064
Kurtosis	10.829	31.585	8.529	59.151	9.416	8.251	23.597	37.859
Observations	535	489	299	133	165	169	94	40

4.2Markov-switching Model Parameter Estimation

A more direct approach would be to estimate one general MS model for all the selected 27 countries which did not experience hyperinflation; however, we had little success with this

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because the system failed to converge[5]. For computational efficiency therefore, we decided to break down the whole lot and present results by income groups. Results are placed in three subsections in line with the objectives of the study: First, using the MS model, we segmented datasets into two states in order to isolate the high inflation periods, then we measured the relative contributions of each country in the high inflation state in order to identify the countries with greater challenges; Second, we discussed specification issues; and finally, we analyzed the similarities in the inflation patterns of the selected countries with a view to investigating the price level convergence among them.

In addition, we should also report that results of the Upper-middle and High Income groups are presented together, due to the fact that the High income group has only one entry, i.e. Seychelles, and therefore has insufficient data to allow MS modeling.

4.2.1 Low Income Group of SSA

Table 2 presented the maximum likelihood estimates of the Markov-switching model parameters for the Low income group in the entire period 1960 – 2019. In addition to analyzing inflation pattern from 1960 – 2019, we also intend to measure the levels of improvement (or otherwise) of the selected countries over time. Thus we divided the entire datasets into two time periods – old (1960 - 2003) and recent (2004 – 2019). Countries such as Mali which only have data for 1989 – 2017 informed our decision to truncate the first subsample at 2003; this will ensure that we have enough data for comparison for each country in both subsamples. Table 2 also contained the MS model estimates for the two subsamples. The following observations are noted.

It is evident that the Markov-switching model identified State 1 as the high inflation regime and State 2 as the relatively stable state in all the three samples.

In 1960-2019, Guinea-Bissau accounted for the largest proportion of the overall high inflation seen in the Low income group inflation; followed by Malawi, Tanzania, Gambia and Madagascar. Togo and Burundi had approximately the same contributions of 12% to the high inflation experienced in the group. Burkina Faso, Ethiopia and Niger were all associated with an inflation rise of approximately 10%. It is noteworthy that Mali had no significant contributions, at 5% level, to the high inflations seen in the income group in the period under investigation.

Comparing Column 6 with 8, we can infer that in recent times, Malawi, Madagascar, Burundi, Gambia and Tanzania continued to experience significant double-digit inflation. Guinea-Bissau, Togo, in contrast, have both significantly improved by 47.7% and 8.5%, respectively. Ethiopian prices which had earlier been stable deteriorated by 24.3% in recent times.

The second segment of Table 2 presented estimations for inflation uncertainty. Estimates revealed that the high inflation state was uniformly approximately three times more volatile than the low inflation state in the three samples. This confirms the Friedman (1977) hypothesis that the high inflation stateis also the highly volatile state.

Further, estimates of the transition probabilitiesrevealed the following; (i) none of the states is permanent since $P_{11}, P_{22} < 1$. This implies that any of the Low income sub-Saharan countries could move from one state to another; (ii) when prices are rising (falling), it is more likely that they continue to rise (fall) than fall (rise) since $P_{11}, P_{22} > P_{12}, P_{21}$;(ii) movement from

[5] The conventional linear model would typically estimate the 27 countries at once; however, it lack features to distinguish between the two different states of high and low inflations (Ayodeji, 2017), which would defeat the purpose of this study.

high to low inflation state is more likely than the other way round ($P_{21} < P_{12}$); (iii) there is higher likelihood that the low inflation periods would persist than the high ($P_{22} > P_{11}$). To buttress the point, expected duration for the high inflation and low inflation states were approximately 4 and 9 years, respectively.

Table 2: Estimates of the Markov-switching model for the Low income group

Description	Parameter	Correspondence	1960 – 2019 State 1	1960 – 2019 State 2	1960 – 2003 State 1	1960 – 2003 State 2	2004 – 2019 State 1	2004 – 2019 State 2
Mean	μ_1	Burkina Faso	0.098 (0.033)	0.011 (0.006)	0.109 (0.041)	0.015 (0.009)	0.045 (0.035)*	0.006 (0.006)*
	μ_2	Burundi	0.123 (0.029)	0.043 (0.009)	0.155 (0.044)	0.043 (0.011)	0.128 (0.032)	0.059 (0.012)
	μ_3	Ethiopia	0.097 (0.026)	0.038 (0.010)	0.078 (0.038)	0.033 (0.013)	0.321 (0.047)	0.077 (0.007)
	μ_4	Gambia	0.201 (0.061)	0.040 (0.006)	0.225 (0.065)	0.037 (0.008)*	0.102 (0.055)*	0.051 (0.006)
	μ_5	Guinea-Bissau	0.489 (0.055)	0.013 (0.008)*	0.521 (0.066)	-0.002 (0.020)*	0.044 (0.036)*	0.017 (0.007)
	μ_6	Madagascar	0.178 (0.036)	0.051 (0.007)	0.233 (0.066)	0.048 (0.010)	0.149 (0.046)	0.075 (0.006)
	μ_7	Malawi	0.260 (0.041)	0.085 (0.010)	0.319 (0.059)	0.096 (0.017)	0.233 (0.049)	0.089 (0.009)
	μ_8	Mali	0.103 (0.097)*	0.010 (0.007)*	0.140 (0.124)*	0.006 (0.012)*	0.039 (0.030)*	0.011 (0.008)*
	μ_9	Niger	0.101 (0.034)	0.004 (0.007)	0.134 (0.053)	0.006 (0.011)	0.065 (0.042)*	0.008 (0.006)*
	μ_{10}	Tanzania	0.237 (0.037)	0.060 (0.007)	0.260 (0.045)	0.066 (0.012)	0.127 (0.036)	0.051 (0.006)
	μ_{11}	Togo	0.126 (0.040)	0.015832 (0.005807)	0.140 (0.045)	0.015 (0.009)*	0.055 (0.037)*	0.014 (0.006)
	α_1	Inflation Lag 1	0.130 (0.083)*	0.267435 (0.037882)	0.067 (0.114)	0.300 (0.042)	-0.137 (0.191)*	0.068 (0.037)*
Volatility	σ	Regime Cond. Std. deviation	0.114 (0.007)	0.0338 (0.0021)	0.117 (0.009)	0.041 (0.003)	0.056 (0.007)	0.016 (0.002)
Transition Probability	P_{11}	Probability of high inflation	0.770		0.718		0.506	
	P_{22}	Probability of low inflation	0.891		0.863		0.787	
	P_{12}	Probability of transiting from high to low	0.231		0.282		0.494	
	P_{21}	Probability of transiting from low to high	0.109		0.137		0.213	

Standard error in parentheses. *not significant at 5%. $^{+}$p-values.

Further information on the inflation pattern of the Low income group can be obtained by plotting the filtered probability against the actual inflation rates. Figure 5 displayed these plots.

If it is assumed, as is usual in practice, that switching has occurred whenever the smoothed probability, $P(S_t = i|\Phi_t) \geq 0.5$, then the probability plot reconstructed all the high inflation episodes in the Low income group inflation rates including the Gambian 1986, the Malawian 1995 and Guinea-Bissau's 1989.

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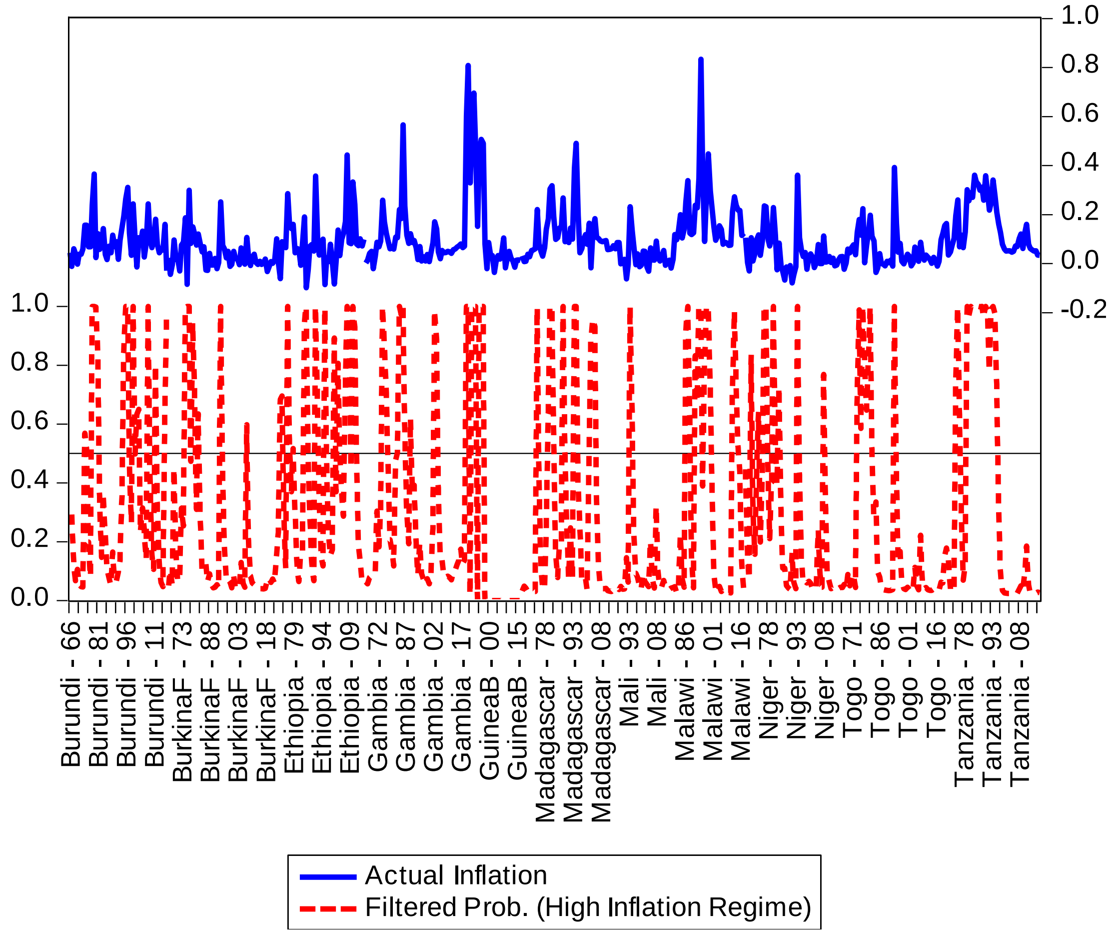

Figure 5: Plot of Inflation Rates (Top Panel) and the Filtered Probability of the High Inflation State (Bottom Panel) for Low Income Group (1960 - 2019)

4.1.2 Lower-Middle Income Group of SSA

Table 3 presented the Markov-switching models estimates for the Lower-middle income group.

It is clear that the Markov-switching model identified State 1 as the high inflation state and State 2 as the relatively stable state.

Between 1960 and 2019, it is obvious that Zambia accounted for the largest proportion of the high inflation episodes experienced in the group. Some significant percentage was also due to Ghana and Nigeria. All other countries in the group had no significant contributions, at the 5% level in the high inflation state. How be it insignificant, the high annual mean inflation rate of 13.5% recorded by Cameroon could be due to the spike in its inflation in 1994.

Comparing the old and the recent inflation rates pattern, it is obvious that the mean annual rates of 59.7% recorded by Zambia between 1960 and 2019 were due to its high inflation experience prior to 1997. It is also obvious that Zambian prices had become more stable in recent times relative to pre-2003, though it is yet to reach the desired <10% mark. We observed further that Nigeria and Ghana continued to experience significant double-digit inflation rates through 1960-2003 and 2004-2019, though price stability had improved greatly. Mauritania and Eswatini had the least significant contributions to SSA high inflation in recent times; while Cameroon, Cote d'Ivoire, Senegal and Cabo Verde displayed significant price stability between 2004 and 2019. It is noteworthy that Kenyan inflation rates had gradually began to deteriorate in recent times as it recorded the highest rise of 15.4%.

Just as in the case of the low income group, the estimates of P_{11} and P_{22} being less than 1revealed that both states are transitory. In other words, any of the Lower-middle income sub-Saharan countries could move from one state to another; though movement from low to high inflation is more likely than the other way round, $\hat{P}_{12} \approx 23.1\%$ but $\hat{P}_{21} \approx 4.3\%$. These statements quite agree with what was visualized in Figure 2 earlier displayed. Secondly, $\hat{P}_{22}$ being much greater than $\hat{P}_{11}$ implied that, in general, low inflation is more likely to persist in the Lower-middle income group of SSA than high. Accordingly, expected duration for a low inflation state is 23 years, whereas that of high inflation is just 4years.

Table 3: Estimates of MS model for the Lower-middle income group

			1960 – 2019		1960 – 2003		2004 – 2019	
Description	Parameter	Correspondence	State 1	State 2	State 1	State 2	State 1	State 2
Mean	μ_1	Cameroon	0.135 (0.314)*	0.023 (0.007)	0.179 (0.457)*	0.035 (0.010)	0.022 (0.0178)*	0.018 (0.006)
	μ_2	Cote d'Ivoire	0.162 (0.726)*	0.015 (0.007)	0.083 (0.252)*	0.028 (0.011)	0.027 (0.018)*	0.009 (0.006)*
	μ_3	Cabo Verde	0.025 (10.518)*	0.018 (0.011)*	0.021 (19.961)*	0.032 (0.023)*	0.030 (0.016)*	0.005 (0.006)*
	μ_4	Eswatini	0.103 (1.232)*	0.042 (0.007)	0.090 (3.125)*	0.062 (0.011)	0.061 (0.021)	0.051 (0.007)
	μ_5	Ghana	0.264 (0.075)	0.058 (0.009)	0.303 (0.083)	0.075 (0.013)	0.122 (0.022)	0.090 (0.010)
	μ_6	Kenya	0.137 (0.215)*	0.040 (0.006)	0.126 (0.218)*	0.053 (0.009)	0.154 (0.023)	0.066 (0.008)
	μ_7	Mauritania	0.060 (10.299)*	0.027 (0.013)	0.057 (21.563)*	0.0349 (0.030)*	0.061 (0.021)	0.034 (0.008)
	μ_8	Nigeria	0.216 (0.111)	0.046 (0.006)	0.293 (0.146)	0.051 (0.009)	0.113 (0.022)	0.085 (0.011)
	μ_9	Senegal	0.108 (0.225)*	0.012 (0.007)*	0.133 (0.280)*	0.020 (0.010)	0.032 (0.020)*	0.004 (0.006)*
	μ_{10}	Zambia	0.597 (0.113)	0.060 (0.009)	0.702 (0.131)	0.140 (0.030)	0.121 (0.024)	0.070 (0.008)
	α_1	Inflation Lag 1	0.342 (0.083)	0.534 (0.028)	0.277 (0.094)	0.414 (0.042)	0.309 (0.154)	0.100 (0.049)
Transition Probability	P_{11}	Probability of high inflation	0.769		0.763		0.442540	
	P_{22}	Probability of low inflation	0.957		0.939		0.725893	
	P_{12}	Probability of transiting from high to low	0.043		0.061		0.274107	
	P_{21}	Probability of transiting from low to high	0.231		0.237		0.557460	
Volatility	σ	Regime Cond. Std. deviation	0.272 (0.022)	0.039 (0.001)	0.283 (0.026)	0.046 (0.002)	0.026 (0.004)	0.016 (0.002)

Standard error in parentheses *not significant at 5% . $^{+}$p-values

In addition, MSM results showed that the high inflation state was, in general, approximately seven times more volatile than the Lower-middle inflation state. Again, in line with the Friedman's (1977) hypothesis, the high inflation state of the Lower-middle income group was more volatile. It is noteworthy that inflation volatility in SSA Lower-middle income group has greatly reduced in recent times. This is not surprising since the three eventful countries in 1960-2003, i.e. Zambia, Ghana and Nigeria, have all experienced significant reductions in their inflation rates.

Further information is contained in the filtered probabilities generated from the MS model. Figure 6 displayed these plots of inflation rates against the filtered probabilities.

It is easily seen that the filtered probability coincided nicely with all the high inflation episodes in the Lower-middle income group inflation rates, including the "deterioration phase" (Alagidede, 2014) Ghana experienced between 1972 – 1982, the Nigerian 1995 high inflation caused by poor monetary policy and pronounced reduction in the global oil prices and the Zambian 1993 high inflation episode which was caused by large depreciation of the kwacha and indiscriminate money supply growth.

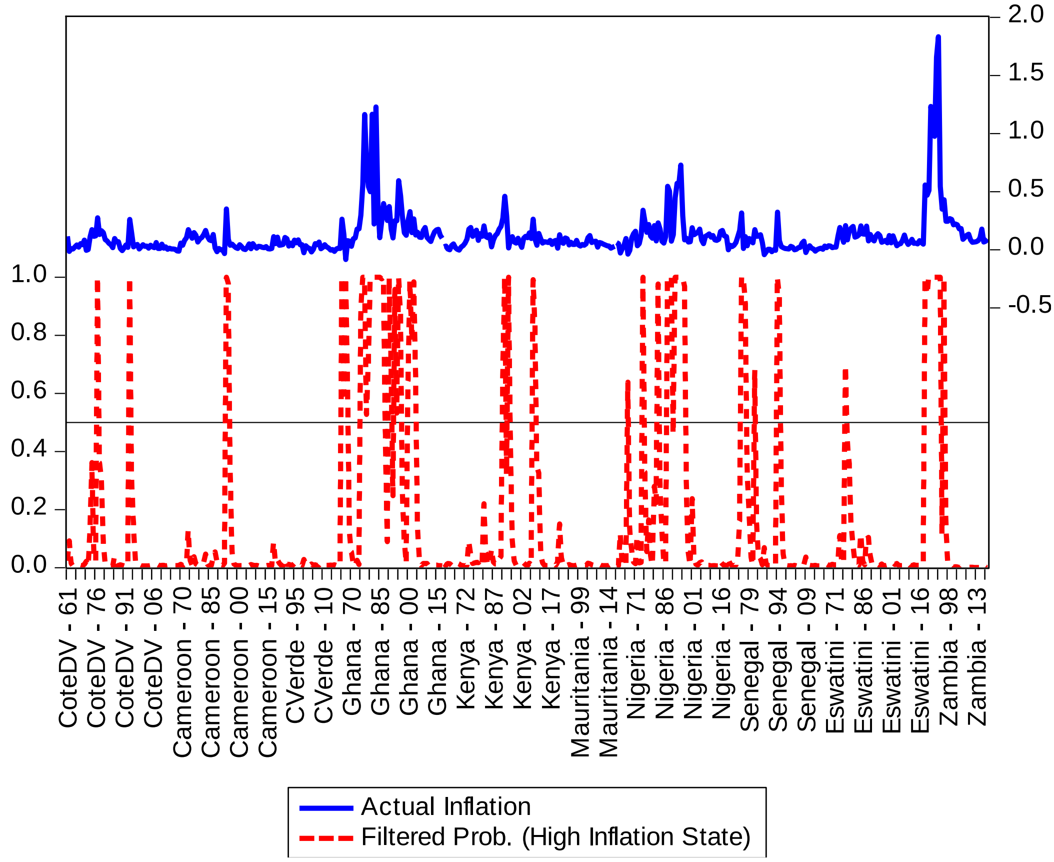

Figure 6: Plot of Inflation Rates (Top Panel) and the Filtered Probability of the High Inflation State (Bottom Panel) for Lower-middle income group

4.1.3Upper-Middle and High Income Group of SSA

Table 4 contained the Markov-switching[6] models estimates for the Upper-middle and High income group. The following observations are noted.

Clearly, the Markov-switching model identified State 1 as the non-tranquil state and State 2 as the relatively stable state.

In 1960-2019, model estimates showed that except for Mauritius and Seychelles, all other 4 countries had no significant contributions to the high inflation episodes in the group. Pockets of inflation spikes which were noticed in Mauritius and Seychelles were caused by substantial devaluation of the rupee (Franses and Janssens, 2018). By and large, inflation rates in the Upper-middle income group have been relatively stable.

Results in Columns 6 and 8 revealed that Gabon, South Africa and Equatorial Guinea had, on the average, consistently experienced low inflation between 1960 and 2019. Mauritius had earlier gone through high inflation in 1994 but quickly recovered in the subsequent years. How

[6] We also experimented with a 3-state MSM. The results however failed to converge.

be it insignificant, we must note that Botswana experienced a spike in inflation rates in 2008; perhaps this explains the14.0% annual mean inflation rates recorded in State 1 of 2004 – 2019.

Table 4: Estimates of the Markov-switching Model for the Upper-middle and High income group

			1960 – 2019		1960 – 2003		2004 – 2019	
Description	Parameter	Correspondence	State 1	State 2	State 1	State 2	State 1	State 2
Mean	μ_1	Botswana	0.076 (0.161)*	0.024 (0.005)	0.101 (0.1492)*	0.025 (0.006)	0.140 (34.171*	0.041 (0.011)
	μ_2	Equatorial Guinea	0.025 (0.033)*	0.011 (0.006)*	0.025 (0.028)*	0.029 (0.012)	0.062 (140.290)*	0.024 (0.016)*
	μ_3	Gabon	0.053 (0.030)*	0.007 (0.004)*	0.060 (0.027)	0.003 (0.005)*	0.032 (119.420)*	0.014 (0.014)*
	μ_4	Mauritius	0.120 (0.047)	0.011 (0.005)	0.110 (0.036)	0.004 (0.005)*	0.083 (70.339)*	0.027 (0.013)
	μ_5	South Africa	0.033 (0.109)*	0.023 (0.004)	0.075 (0.101)*	0.022 (0.005)	0.074 (31.526)*	0.033 (0.014)
	μ_6	Seychelles	0.104 (0.042)	0.010 (0.004)	0.115 (0.046)	0.009 (0.005)*	0.332 (8.803)*	0.019 (0.007)
	α_1	Inflation Lag 1	0.308 (0.144)	0.722 (0.037)	0.490 (0.146)	0.716 (0.066)	-0.485 (23.919)*	0.363 (0.121)
	α_2	Inflation Lag 2	NA	NA	-0.319 (0.164)	0.039 (0.055)*	NA	NA
Transition Probability	P_{11}	Probability of high inflation	0.766		0.802		0.643	
	P_{22}	Probability of low inflation	0.951		0.930		0.987	
	P_{12}	Probability of transiting from high to low	0.232		0.198		0.357	
	P_{21}	Probability of transiting from low to high	0.049		0.070		0.013	
Volatility	σ	Regime Cond. Std. deviation	0.112 (0.013)	0.023 (0.001)	0.097 (0.011)	0.020 (0.002)	0.022 (0.003)	0.156 (2.674)

Standard error in parentheses *not significant at 5%. NA means Not Applicable

In general, $\hat{P}_{11} > \hat{P}_{22}$ implies that the likelihood that the selected countries would experience high inflation is much less than that of the low inflation. In addition, $\hat{P}_{21} < 10\%$ also implies that once the inflation rate system enters into low inflation state, it is less likely to leave the state. Consequently, expected durations for price stability and the non-tranquility states imply that the low inflation phases could be approximately four times as long as the high inflation periods. In other words, high inflation is not likely to persist in the Upper-middle and High income group.

Estimates of volatility showed that the low inflation state is also the low fluctuation state. This again confirms Friedman's hypothesis.

Figure 7 plotted the actual inflation rates against the filtered probabilities obtained from MS modeling. It is easily seen that the filtered probability reconstructed all the high inflation episodes in the Upper-middle and High income group inflation rates.The MS modeling ignored most of the South African inflation spikes as they were clearly not relatively pronounced when compared with the other members in the group. However, it captured the case of 2004 – 2008, when inflation rates increased from deflation (-0.65) to high inflation (10.06).

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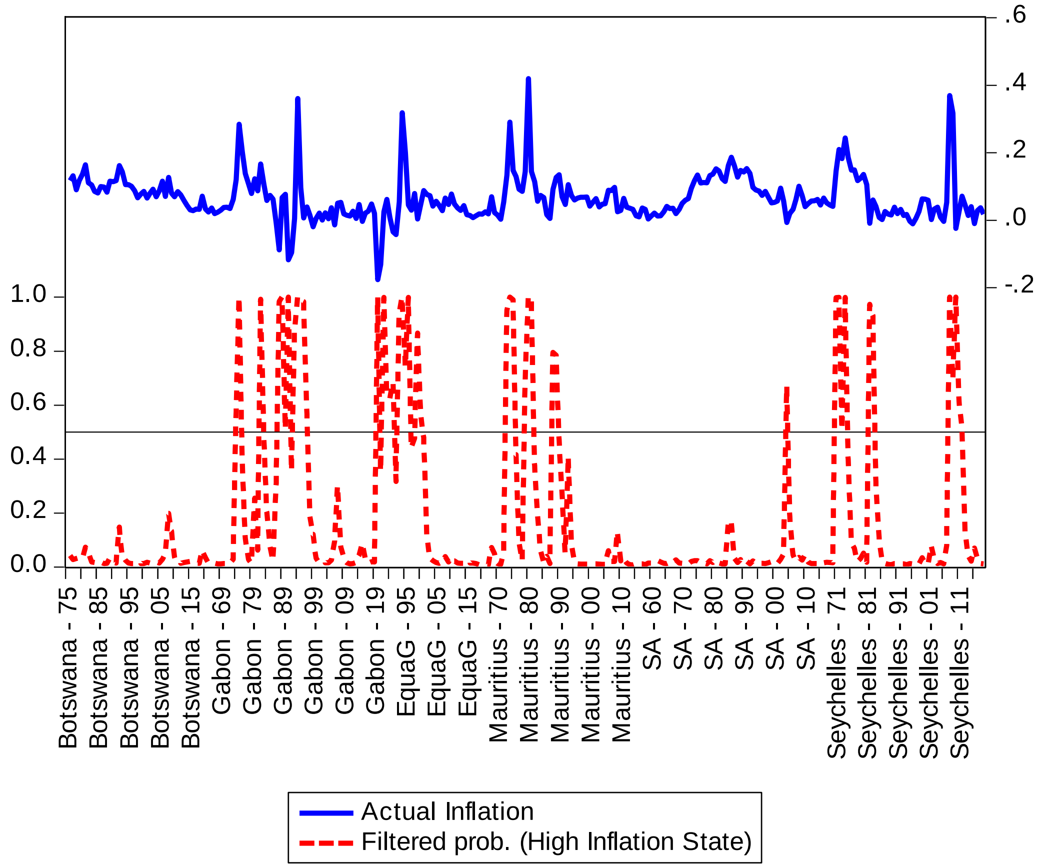

Figure 7: Plot of Inflation Rates (Top Panel) and the Filtered Probability of the High Inflation State (Bottom Panel) for Upper-middle and High Income group

4.1.4 The Hyperinflation Group

Table 5 referred to the Markov-switching parameter estimates for the hyperinflation group. Unlike the first three groups, the two states identified in this group are the hyperinflation and low inflation.

We note, in passing, that all the coefficients in State 1 (1960-2019) were insignificant at the 5% level. Two things may be responsible; (i) there may not be enough hyperinflation swings for each country; or (ii) the fluctuations inherent in the data may require a more technical specification (such as MS-GARCH) for modeling. How be it insignificant, since the estimates were consistent with the pattern in Figure 4, we assume that they provided enough information to be able to analyze (though with great caution) the inflation pattern of the SSA countries during hyperinflation. Hence, the following observations are noted.

It is obvious that Zimbabwe accounted for the largest proportion of the variations seen between 1960 and 2019. Some substantial percentage was also due to Congo. The descending order of mean contributions of each country is as follows: Zimbabwe had the highest with hyperinflation rates of 4697.4% and a low inflation of 5.9%; followed by Congo with average annual hyperinflation rates of 3385.6%, and low inflation rates of 10.7%; Angola followed at a distance with a mean rates of 1174.1% and 3.5% hyperinflation and low inflation rates, respectively.

In order to assess the improvement of the group members over time, we also divided the datasets into two subsamples. Our analysis failed to converge for sample 2004 – 2019: Observing Figure 4 very closely, we reckoned that this could be due to the outlying observations from Zimbabwe. Instead we analyzed for 1960 – 2007 and 2008 – 2019.Results were also displayed in Table 5.

We observed significant improvements, especially in Congo and Zimbabwe. It is noteworthy that Zimbabwe had no significant (at 5% level) contributions to the high inflation rates experienced between 2008 and 2019. Angola also made some significant progress from the hyperinflation zone to high inflation state within the last 12 years. .

Table 5: Estimates of the Markov-switching Model for the Hyperinflation Group

			1960 - 2019		1960 - 2007		2008 – 2019	
Description	Parameter	Correspondence	State 1	State 2	State 1	State 2	State 1	State 2
Mean	μ_1	Angola	11.741 (92.971)*	0.035 (0.057)*	11.749 (112.468)*	-0.069 (0.082)*	0.2995 (0.102)	0.029 (0.031)*
	μ_2	Congo	33.857 (42.578)*	0.107 (0.024)	31.044 (50.911)*	0.136 (0.030)	0.094 (0.055)	0.010 (0.013)*
	μ_3	Zimbabwe	46.974 (38.951)*	0.052 (0.043)*	51.737 (42.176)	0.060 (0.056)*	0.005 (0.222)*	-4.27E-05 (0.004)*
	α_1	Inflation Lag 1	-0.107 (0.767)*	0.684 (0.026)	-0.010 (0.844)	0.683 (0.018)	-0.073 (0.364)*	0.719 (0.261)
Volatility	σ	Regime Cond. Std. deviation	60.740 (13.198)	0.155 (0.008)	64.451 (16.202)	0.183 (0.013)	0.058 (0.019)	0.016 (0.004)
Transition Probability	P_{11}	Probability of hyper/high inflation	0.813		0.792		0.849	
	P_{22}	Probability of low inflation	0.949		0.926		0.948	
	P_{12}	Probability of transiting from hyper/high to low	0.187		0.208		0.151	
	P_{21}	Probability of transiting from low to hyper/high	0.051		0.074		0.052	

Standard error in parentheses *not significant at 5%

In general, volatility shot above 6000% during hyperinflation! Thus it is not only true that the high inflation state is also the highly volatile state but, in addition, volatility increases with increasing inflation rates, with the hyperinflation state being the most volatile. On a positive note, we observed further that volatility reduced by a whopping 6439.2% in recent times.

Estimates of the transition probabilitiesrevealed, (i) movement from low to hyperinflation state is very unlikely (P_{21} = 5.1%); (ii) there is high likelihood that hyperinflation persists in member countries (P_{11} = 81.3%); however (iii) there is higher likelihood that the low inflation periods would be longer that the hyperinflation (P_{22} = 94.9%). To buttress the point, expected duration for the hyperinflation and low inflation states were approximately 5 years and 20 years, respectively; indicating that the phases of the hyperinflation periods have shorter durations than those of the low inflation.

Further information can be extracted from plotting the filtered probability graphs against the inflation rates. Figure 8 displayed these plots.

Again, we assumed that switching has occurred whenever the filtered probability $\left(P\left(S_t = i \middle| \Phi_t\right)\right) \geq 0.5$. Thus the filtered probability reconstructed all the hyperinflation episodes in the group.

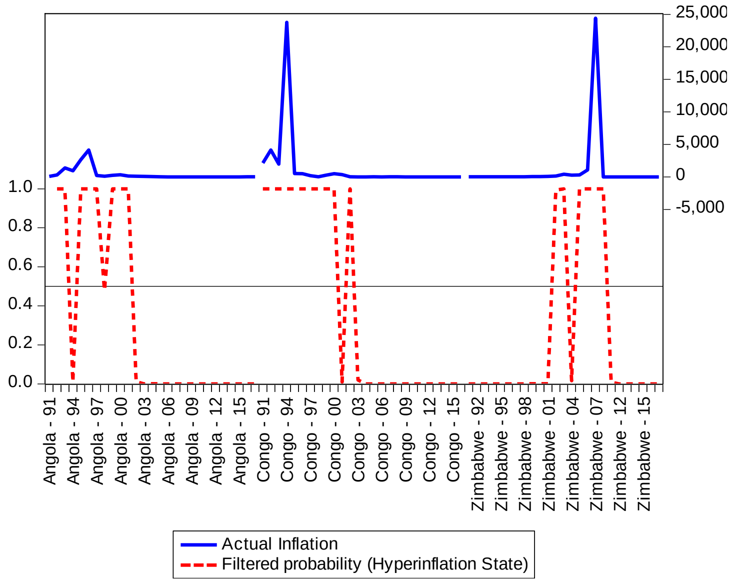

Figure 8: Plot of Inflation Rates (Top Panel) and the Filtered Probability of the Hyperinflation State (Bottom Panel) for Hyperinflation Group

4.2 Specification Testing

In a 'single-state' specification, diagnostics test would typically be based on the standardized residuals; however Maheu and McCurdy (2000) already cautioned that probabilities for MS specification are usually not valid since asymptotic results are not available. Hence, we construct a simple alternative test.

A simple test of model adequacy can be constructed analogously to the conventional linear model counterpart. In the linear model, we test the hypothesis that all the parameters jointly varnish. In the same vein, we reckoned that if indeed a Markov-switching is inadequate, then all the parameters in State 1 would jointly be equal to the corresponding parameters in State 2; i.e.

$$H_0 : \mu_i = \mu_j \forall i, j, i \neq j \quad (10)$$

In addition, we also test the hypothesis that the volatilities in the two states are different. This, of course, would be a necessary condition for the Friedman's (1977) hypothesis to hold. The relevant null hypothesis in this case is

$$H_0 : \sigma_i = \sigma_j, i \neq j \quad (11)$$

Since all the parameters of the Markov-switching models are known under the stated null hypotheses, we may therefore test them using standard theory of distribution. Wald's statistics and p-values for the relevant associated hypotheses were displayed in Table 6.

Results presented here confirmed that the MS model employed was adequate in the cases of the Low and Lower-middle income groups. As for the Upper-middle &High and the hyperinflation groups, Wald's statistic presented here being insignificant could signify two things; (i) there may not be enough swings in the data to distinguish one state from the other; or (ii) the fluctuations inherent in the data may require a more technical volatility specification (such as MS-GARCH) for modeling.

In the case of the Upper-middle and High income group, we probed further to investigate why Wald's statistic was insignificant. We conducted Wald's test for each of the 6 countries and discovered that the means for states 1 and 2 were not significantly (at 5% level) different from each other except for Mauritius and Seychelles. Thus it can be inferred that there were not enough swings to justify the use of the MS model.

On the other hand, we recall from Figure 4 that there were three clear cases of hyperinflation, providing motivation for the use of the MS modeling of the Hyperinflation group. We conclude therefore that the fluctuations inherent in the data require a more technical specification (such as MS-GARCH) for modeling.

Lastly, $W_{(volatility)}$, the Wald statistic testing the difference in volatility levels of the two regimes was highly significant for all groups; indicating that the high inflation period was indeed more volatile than the price stability state in the cases of the Low, Lower-middle, Upper-middle and Highincome groups; and that the hyperinflation period was more volatile than the low inflation state in the case of the hyperinflation group.

Table 6: Hypothesis Testing by Group

Group	Model adequacy	Volatility
Low income	163.095 (0.000)	253.703 (0.000)
Lower income	35.484 (0.000)	450.953 (0.000)
Upper-middle and High income	10.682 (0.153)	189.100 (0.000)
Hyperinflation	2.49757 (0.645)	707.445 (0.000)

p-values in parentheses

4.3Inflation Convergence Analysis

One of the objectives of study is to assess the level of inflation convergence among the SSA countries in recent times. This is with a view to investigating whether or not the sub-Saharan Africa is truly ready for a monetary union. If macroeconomic convergence is not achieved to a reasonable extent, then a repeat of *brexit* is imminent. MS model employed here allows us to study the similarity among countries when prices are rising and falling. Figures 9 and 10 plotted the annual average inflation rates obtained for each country. These means were extracted from the columns labeled ‘2004 – 2019’in Tables 2 – 4 and ‘2008 – 2019’ in Table 5. The following inferences can be drawn.

Whether prices are rising or falling, the following countries were able to achieve the <10% mark between 2004 and 2019: Burkina Faso, Guinea-Bissau, Mali, Niger, Togo, Cameroon, Cabo Verde, Cote d’Ivoire, Eswatini, Mauritania, Senegal, Equatorial Guinea, Gabon, Mauritius, South Africa, Congo and Zimbabwe. Thus 45% of the countries in the Low income group, 60% of the Lower-middle, 67% of the Upper-middle& High group, and 67% of the Hyperinflation group have achieved the single-digit inflation mark.

Results here have important implications for the proposed monetary unions since 11 out of 15 ECOWAS countries were included in this study. From Figure 10 below, it is easily seen that Togo and 7 other countries met the single-digit criterion between 2004 and 2019. These other countries includeBurkina Faso, Guinea-Bissau, Mali, Niger, Cabo Verde, Cote d’Ivoire and Senegal. Our results therefore lend empirical support to the statement by the President of the ECOWAS Commission, Jean-Claude Kasi that members have made significant progress in several areas to achieve the monetary convergence.

In the same vein, 3 out of 5 East African Community (EAC), Burundi, Kenya and Tanzania, were included in this study. It is easy to see that none of them attained the single-digit between 2004 and 2019; however, it could also be inferred that with average high inflation rates ranging between 12.8% and 15.4%, they should be able to institute a monetary union in 2024 if

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they continue to make efforts at reducing the inflation rates. Our findings agreed with Nguyen and Jemma (2017) and Mose and Kaboro(2019).

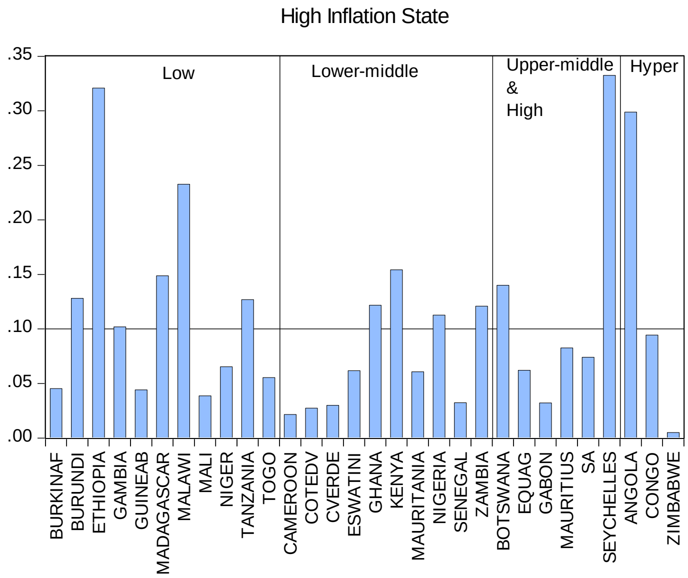

Figure 9: A bar chart of annual average inflation rates in the high inflation state in SSA

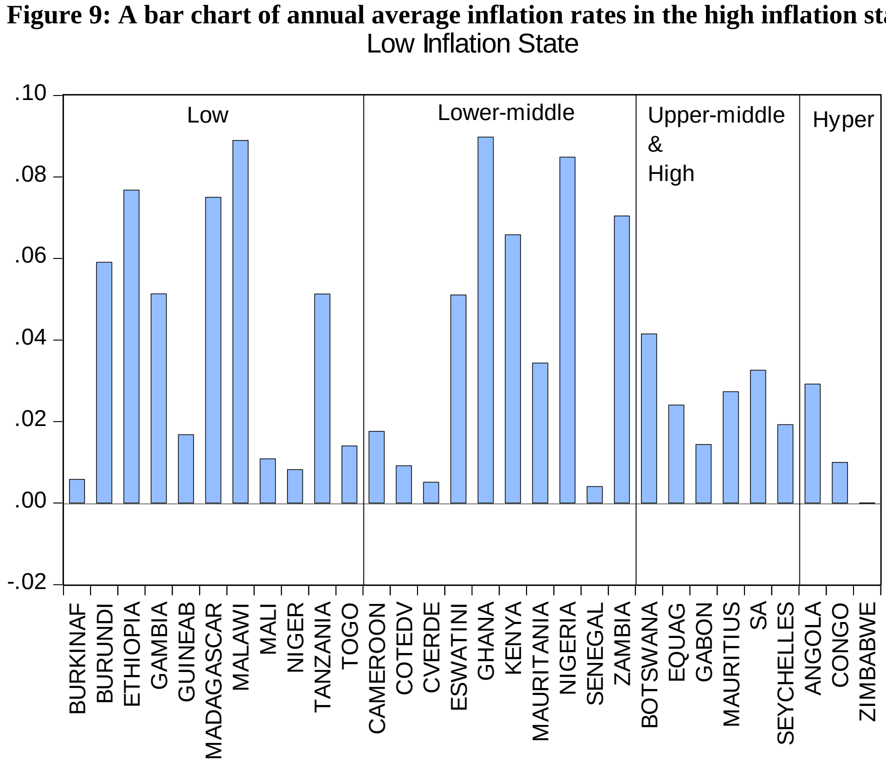

Figure 10: A bar chart of annual average inflation rates in the low inflation state in SSA

5. Conclusion and Recommendations

The major objective of the study isto model inflation in SSA with a view to identifying the member countries having greater inflation challenges and also make appropriate recommendations. Subsequently, results obtained will be usedto investigate the similarity level in the inflation pattern among SSA countries with a view to assessing the readiness of Africa to establish proposed monetary unions. 30 countries, including the 3 countries which have earlier experienced hyperinflation, were selected to be studied between 1960 and 2019. The Markov-switching model was employed to segment the inflation rates into different states – stable, high and hyperinflation. For computational efficiency and comprehensive analysis, estimation results were presented by income groups.

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In the Low income group of SSA, Guinea-Bissau accounted for the largest proportion of the overall high inflation between 1960 and 2019; followed by Malawi, Tanzania, Gambia and Madagascar. Togo and Burundi, on one hand, and Burkina Faso, Ethiopia and Niger, on the other had approximately the same contributions; whereas Mali had no significant contributions, at 5% level, to the high inflations seen in the Low income group between 1960 and 2019. Comparing old and recent subsamples of 1960 – 2019, we inferred that Malawi, Madagascar, Burundi, Gambia and Tanzania had consistently experienced significant double-digit inflation. Guinea-Bissau and Togo have both improved significantly by 47.7% and 8.5%, respectively; whereas Ethiopian prices, in contrast, which had earlier been stable deteriorated by 24.3% in recent times.

In the Lower-middle income group of SSA, it is obvious that Zambia accounted for the largest proportion of the high inflation experienced between 1960 and 2019. Some substantial percentage was also due to Ghana and Nigeria. All other countries in the group had no significant contributions, at the 5% level, in the high inflation state. Comparing the old and the recent inflation rates pattern, we observed that Zambian prices had become more stable in recent times relative to pre-2003, though it is yet to reach the desired <10% mark. We observed further that Nigeria and Ghana continued to experience significant double-digit inflation rates through 1960-2003 and 2004-2019, though price stability had improved greatly. Mauritania and Eswatini had the least significant contributions to SSA high inflation in recent times; while Cameroon, Cote d'Ivoire, Senegal and Cabo Verde displayed significant price stability between 2004 and 2019. It is noteworthy that Kenyan inflation rates had gradually began to deteriorate in recent times as it recorded the highest rise of 15.4%.

In the Upper-middle and High income group, model estimates showed that except for Mauritius and Seychelles, all the remaining 4 countries did not significantly influence the aggregate high inflation in the group. By and large, inflation rates in the Upper-middle income grouphave been relatively stable. Subsample results revealed that Gabon, South Africa and Equatorial Guinea had, on the average, consistently experienced low inflation between 1960 and 2019.

Lastly, in the hyperinflation group, results showed significant improvements in Congo and Zimbabwe between 2008 and 2012. Angola also made some significant progress from the hyperinflation zone to high inflation state within the last 12 years.

In view of inflation fluctuations, results revealed that volatility increases with increasing inflation rates, the hyperinflation being the most volatile state.

Our results also have important implications for the proposed monetary unions: Togo, Burkina Faso, Guinea-Bissau, Mali, Niger, Cabo Verde, Cote d'Ivoire and Senegal met the single-digit criterion between 2004 and 2019. Our results therefore lend empirical support to the statement by the President of the ECOWAS Commission, Jean-Claude Kasi that members have made significant progress in several areas to achieve the monetary convergence.

In addition, though none of Burundi, Kenya and Tanzania attained the single-digit between 2004 and 2019; yet, with average rates ranging between 12.8% and 15.4%, it is clear that the East African Community (EAC) has also made significant progress, and with consistent effort should be able to institute a monetary union in 2024.

The fact that almost all the country-specific coefficients included in the MS modeling were significant suggested that beyond addressing regional problems, economic institutions such as IMF and World Bank should consider creating more country-specific interventions purposely to address source(s) of high inflation in countries like Burundi, Gambia, Madagascar, Malawi, Tanzania, Ghana, Kenya, Zambia, Nigeria, Botswana; and especially, Ethiopia, Seychelles and

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Angola.

Further, Figure 9 showed that the countries with greatest inflation challenges in the recent times are Ethiopia, Seychelles and Angola. Previous studies have identified sources of these countries' spikes in inflation. They includedepreciation of the local currency, global economic crisis leading to significant reduction in foreign direct investment,surge in food prices, poor monetary policies leading to indiscriminate increase in the aggregate money supply growth and poor foreign exchange rates(Barnichon and Peiris, 2007; Franses and Janssens, 2018). Some viable solutions to these problems include increase in the level of productivity, making and implementing appropriate monetary policies and fiscal discipline.

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Appendix

Table 8: List of Selected Countries and other Details

ID No.	Group	Country	Start year of data	End year of data
1	Low income	Burkina Faso	1960	2019
2		Madagascar	1965	2018
3		Gambia	1962	2019
4		Burundi	1966	2018
5		Tanzania	1966	2019
6		Togo	1967	2018
7		Guinea-Bissau	1988	2017
8		Mali	1989	2017
9		Malawi	1981	2018
10		Ethiopia	1966	2017
11		Niger	1964	2018
12	Lower-middle income	Ghana	1965	2018
13		Nigeria	1960	2019
14		Cote d'Ivoire	1961	2019
15		Kenya	1960	2018
16		Eswatini	1966	2018
17		Cabo Verde	1984	2019
18		Zambia	1986	2019
19		Senegal	1968	2018
20		Cameroon	1969	2018
21		Mauritania	1986	2018
22	Upper-middle income	South Africa	1960	2019
23		Mauritius	1964	2019
24		Botswana	1975	2018
25		Gabon	1963	2019
26		Equatorial Guinea	1986	2018
27	High income	Seychelles	1971	2019
28	Hyperinflation	Angola	1991	2018
29		Congo DR	1964	2016
30		Zimbabwe	1964	2017

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Table 9: Panel Unit Root Test

Group	Levin, Lin & Chu	Im, Pesaran and Shin	ADF	PP
Low income	-7.879	-8.040	111.576	155.288
	(0.000)	(0.000)	(0.000)	(0.000)
Lower-middle income	-5.438	-5.326	70.477	126.882
	(0.000)	(0.000)	(0.000)	(0.000)
Upper-middle and High income	-4.495	-5.368	56.956	57.071
	(0.000)	(0.000)	(0.000)	(0.000)
Hyperinflation	-5.346	-4.396	32.792	63.246
	(0.000)	(0.000)	(0.000)	(0.000)

p-values in parentheses

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