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Markov-Switching Regression Model on the Relationship between GDP and Inflation in Nigeria.

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Abstract

Application of Markov-switch models to Nigeria's economy especially the macroeconomic variables in order to determine how it relates to policy making cannot be under-emphasized. This study investigates the relationship between gross domestic products and inflation in Nigeria using a time series data from 1960 – 2019 with the aid of Markov switching regression model. Markov switching vector autoregressive (MSVAR) model is used to determine the structure of inflation in Nigeria. The results from this study concludes that the Markov-Switching Regression model is a high-degree flexible model having captured regime shifts in the mean, variance and the parameters of the vector autoregressive process. Also, it is observed that inflation series is well fitted by the MSVAR model and the filtered probabilities can be deduced. This was accounted for by the estimated parameters and the filtered probability plots of regime 1 and 2 and they have high transition probabilities of 0.985513 and 0.97144. The expected durations that corresponds the probability in a regime are 69 and 35 respectively showing that inflation on the economic growth will remain in the origin state almost two times before moving to the second state. Hence, this study concludes that there is regime switching structure in the dataset.

Keywords: *Gross domestic product, Inflation, Regime Switch, Probability, MSVAR.*

Introduction

Inflation has been defined by scholars in so many different ways in the literature. Modellings of inflation in most cases have specified the inflation procedure as a function of a wideset of macroeconomic and policy-related variables, often involving complicated dynamic structures[3]. Since the 1990s, recognizing that structural changes are key in understandingtime series variables, Markov-switching models have become ubiquitous in analyzingprocesses, such as inflation, that may be subject to occasional, discrete shifts over time.

The problem of inflation surely is not a new process and it has been a major problem in the country over the years. To attain sustainable economic growth coupled with price stability continues to be the central objective of macroeconomic policies for most countries in the world today[2].

Frequently, inflation is thought of as being a highly persistent variable. However, empirical studies have found lower persistence during monetary policy regimes that have precisely targeted inflation. A very persistent low rate of inflation can be seen as desirable if the rate is in line with a central banks definition of price stability [10]. Macro-economic variables typically and persistently fluctuate around high and low levels, this one may lead to the possibility of a regime shift and an unobservable Markov process.An appropriate method that can fascinate the unobservable state, the transmission from one regime to another and the duration of stay in a particular regime often ignored by the linear methods is the Markov-Switching Variance Autoregressive model. The MS-VAR model can provide a systematic ability to implementing statistical methods and the model can also estimate an efficient and consistent parameters, detect recent changes and correct the VAR model when the regimes change [9].

The aim of this study is to apply Markov-switch model to the relationship between GDP and inflation in Nigeria economy. The rest of the paper is structured as follows: Section two is about the methodology, while section three presents the empirical result and section four concludes the study.

Methodology

This study uses annual Nigeria data for the period of 1960 – 2019 to test whether there is regime shift between GDP and inflation applying Markov-switching regression models. The data was obtained from World Development Indicator database. The variables were converted to logarithm to avoid spurious rejection. The E-views 10 statistical package was used to carry out the analysis in this study

Model specification

Augmented Dickey-Fuller model can be written as follows:

$Yt = \rho Yt-1 + \varepsilon_t$…………………………………………… (1)

The model can be written by adding a constant and a trend to it and becomes:

$Yt = \rho Yt-1 + \alpha + \beta t + \varepsilon_t$ …………………………………. (2)

Where ε_t are independent identically distributed variables that follow a normal distribution; $N(0, \sigma^2)$ and t = 1,2,…

The test statistic is the τ statistic on the lagged dependent variable. The relevant root null hypothesis is if the absolute value of the calculated ADF statistic(τ) is higher than the significant level, the series is not stationary and if the p-value is less than the significant level, the series is stationary[8]

We can make use of differencing to make the time series stationary. The differenced series can be written as,

$v_t' = v_t - v_{t-1}$ ……………………………………… (3)

This is the first difference of v, at period t.

Testing for the unit root in the vector autoregressive (VAR) model, the absolute of the eigenvalues of the matrix can be sought for and must be precisely the real numbers that satisfy the equation

$$\det(A - \lambda I) = 0 \text{ …………………… (4)}$$

The VAR structure is considered stable if all the unit roots lie inside the unit circle and the modulus is less than one.

If for instance, the random variable of interest v_t follows a process that depends on the value of an unobserved discrete state variable s_t,then there is an assumption that there are N possible regimes, and it is said to be in state or regime *n*in period *t* when $s_t = n$, for n= 1, …, N.

The switching model assumes that there is a different regression model associated with each regime, and that the regression errors are normally distributed with variance that may depend on the regime[8].

The first-order Markov assumption requires that the probability of being in a regime depends on the previous state, so that

$(s_t = j \mid s_{t-1} = i) = (t)$ …………………….. (5)

This probabilities are assumed to be time-invariant so that $p_{ij}(t) = p_{ij}$ for all t, but this restriction is not required.

This probabilities can be written in a transition matrix

$$p\ (t) = \begin{pmatrix} p_{11}(t)...p_{1M}(t) \\ .... \\ .... \\ p_{M1}(t)...p_{MM}(t) \end{pmatrix} \quad …………………… (6)$$

Where, the *ij*-th element represents the probability of transitioning from regime I in period t – 1 to regime j in period t.

This follows the study of Diebold as contains in[8];

$p_{11}(t) = p(s_t = 1 \mid s_{t-1} = 1, X_{t-1}; \beta_i) = \exp (X_{t-1}{'}\ \beta_1) / 1 + \exp (X_{t-1}{'}\ \beta_1)$, $p_{1M}(t)$ $= (1 - p_{11}(t))$.

Also,

$P_{MM}(t) = p(s_t = M \mid s_{t-1} = M, X_{t-1}; \beta_M) = \exp (X_{t-1}{'}\ \beta_M) / 1 + \exp (X_{t-1}{'}\ \beta_M)$, $p_{M1}(t)$

$= (1 - p_{MM}(t))$.

This study made use of a two state Markov process which indicates that M =2. The two transition probabilities are time-varying, they evolve as a logistic functions of $X_{t-1}{'}\beta_i$,i = 1,2 , where the vector X_{t-1} includes economic variables that affect the state transition probabilities. The two sets of parameters governing the transition probabilities are a (2k x1) vector, $\beta=(\beta_1{'}, \beta_2{'})$.

Regarding the simple switching model, the probabilities may be parameterized in terms of a multinomial logic. Note that since each row of the transition matrix specifies a full set of conditional probabilities, a separate multinomial specification for each row iof the matrix is defined as,

$(V_{t-1},) = exp(V_{t-1,ij}) / \sum_{s=1}^{M} \ exp(V_{t-1}, \delta_{is})$ …………………….. (7)

For, $j = 1, …,M$ and $i= 1, …, M$ with the normalizations $\delta_{iM} = 0$.

The Markov property of the transition probabilities can be evaluated recursively, each step begins with filtered estimates of the regime probabilities for the previous period. Given filtered probabilities, $P(s_{t-1} = m \mid \Im_{t-1})$, the recursion may be broken down into four steps:

$p(s_t = m \mid \Im_{t-1}) = \sum_{j=1}^{M} \ (s_t = m \mid s_{t-1}=j) \ . \ p(s_{t-1}=j \mid \Im_{t-1})$

$= \sum_{j=1}^{M} (V_{t-1},\delta_j).\ p(s_{t-1}=j|\ \Im_{t-1})$ …………………………………….. (8)

Equation (8) forms the one-step ahead predictions of the regime probabilities using basic rules of probability and the Markov transition matrix.

$f(v_t, s_t = m|\Im_{t-1}) = 1/\sigma m\ \phi\ (y_t - \mu_t\ (m)\ )\ .\ p(s_t = m|\ \Im_{t-1})$ ………………. (9)

These one-step ahead probabilities are used to form the one-step ahead joint densities of the data and regimes in period as giving by equation (9) above.

The likelihood contribution for period is obtained by summing the joint probabilities across unobserved states to obtain the marginal distribution of the observed data:

$L_t\ (\beta, \gamma, \sigma, \delta\ ) = f(v_t\ |\Im_{t-1}) = \sum_{j=1}^{M} f(\ v_t, s_t = j\ |\ \Im_{t-1})$ …………………… (10)

Finally, the probabilities are filtered using the results in Equation (7) to update one-step ahead predictions of the probabilities:

$(s_t = m\ |\ \Im_t\ ) = (\ v_t,\ s_t = m\ |\ \Im_{t-1})/\ \sum_{j=1}^{M} f(\ v_t,\ s_t = j\ |\ \Im_{t-1})$ …………………..

(11)

These steps are repeated successively for each period, t = 1, …,T. All that is required for implementation are the initial filtered probabilities, $P(s_0 = m|\Im_0)$, or alternately, the initial one-step ahead regime probabilities $P(s_1 = m|\Im_0)$.

Given parameter estimates of the model, inference can be made on s_t using all the information in the sample by using Hamilton[4] filter as in[7]. Thus, we can get the filtered regime probabilities of GDP on inflation.

Results and Discussion

Augmented Dickey-Fuller unit root test

The Hypothesis is as below:

H_0: There is presence of unit root in the data.

H_1: There is no presence of unit root in the data.

Table 1: ADF unit root test of the GDP

Null Hypothesis: GDP has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on AIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.818601	0.6827
Test critical values:	1% level	-4.127338	
	5% level	-3.490662	
	10% level	-3.173943	

*MacKinnon (1996) one-sided p-values.
Source: Author's computation, 2021.
Interpretation and discussion:
The p-value computed here in table 1 above is greater than the significance level of 0.05, the null hypothesis cannot be rejected and hence concludes that there is presence of unit root in the series. Because of the presence of unit root, we have to first difference it.

Table 2: ADF unit root test of differenced GDP
Null Hypothesis: D(GDP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on AIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.298138	0.0003
Test critical values:	1% level	-4.127338	
	5% level	-3.490662	
	10% level	-3.173943	

*MacKinnon (1996) one-sided p-values.

,
Source: Author's computation, 2021.
Interpretation and discussion:
The computed p-value in table 2 is less than the significance level of $\alpha = 0.05$, the series has been integrated of order 1, the null hypothesis is now rejected, implying that there is no presence of unit root in the series. Hence, the series is said to be stationary.

Augmented Dickey-Fuller unit root test for inflation

The Hypothesis is as below:

H_0: There is presence of unit root in the data.

H_1: There is no presence of unit root in the data.

Table 3: ADF unit root test of the inflation

Null Hypothesis: INFLATION has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on AIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.013735	0.0136
Test critical values:	1% level	-4.127338	
	5% level	-3.490662	
	10% level	-3.173943	

*MacKinnon (1996) one-sided p-values.

Source: Author's computation, 2021.

Interpretation and discussion:

The p-value in table 3 indicates that there is no unit root in the data since the value is 0.0136 < 0.05. The series here is stationary at level and is significant as the test statistic is greater than the critical value at 5%.

Table 4

Null Hypothesis: D(INFLATION) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 3 (Automatic - based on AIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.972465	0.0000
Test critical values:	1% level	-4.137279	
	5% level	-3.495295	
	10% level	-3.176618	

*MacKinnon (1996) one-sided p-values.
Source: Author's computation, 2021.
Interpretation and discussion:
In table 4 above, the result of ADF is stationary at both level and first difference since the test statistic of 5.972465 is greater than the critical value of 3.495295 at 5% level.

Table 5
Dependent Variable: GDP
Method: Markov Switching Regression (BFGS / Marquardt steps)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Regime 1				
C	4.65E+10	1.34E+10	3.477673	0.0005
INFLATION	2.16E+08	5.36E+08	0.402173	0.6876
Regime 2				
C	4.21E+11	7.40E+10	5.690958	0.0000
INFLATION	-2.10E+09	6.20E+09	-0.338387	0.7351
Common				
LOG(SIGMA)	24.78200	0.098935	250.4881	0.0000
Transition Matrix Parameters				
P11-C	4.219891	1.199425	3.518262	0.0004
P21-C	-3.526974	1.516431	-2.325838	0.0200

Mean dependent var	1.25E+11	S.D. dependent var	1.56E+11
S.E. of regression	6.90E+10	Sum squared resid	2.57E+23
Durbin-Watson stat	0.468040	Log likelihood	-1550.862
Akaike info criterion	52.80887	Schwarz criterion	53.05536
Hannan-Quinn criter.	52.90509		

Source: Author’s computation, 2021.

Interpretation and discussion:

From table 5, we can see the differences in the regime specific coefficients (Regime 1: 46466933804.9, Regime 2: 421305185296), which Hamilton(1990) as in [8] termed the fast and slow supports the growth rates for Nigeria economy for the period under study. It can also be observed that regime are significant at 5% level meaning that the dynamics of both regimes are substantial. The transition matrix parameters and log(sigma) also indicated significance in the model. The parameter is more stable in regime 2 meaning that inflation reduced during regime 2.

Table 6

Estimation Equation:

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1: GDP = 46466933804.9 + 215505778.879*INFLATION

2: GDP = 421305185296 - 2097805121.86*INFLATION

SIGMA = @EXP(24.782001602)

Interpretation and discussion:

The estimation here in table 6 implies that the growth rate increases as the unit of inflation increases in equation 1 while there is decrease in the rate of inflation in equation 2. Thus the economy is more stable as there is decrease in inflation during this period.

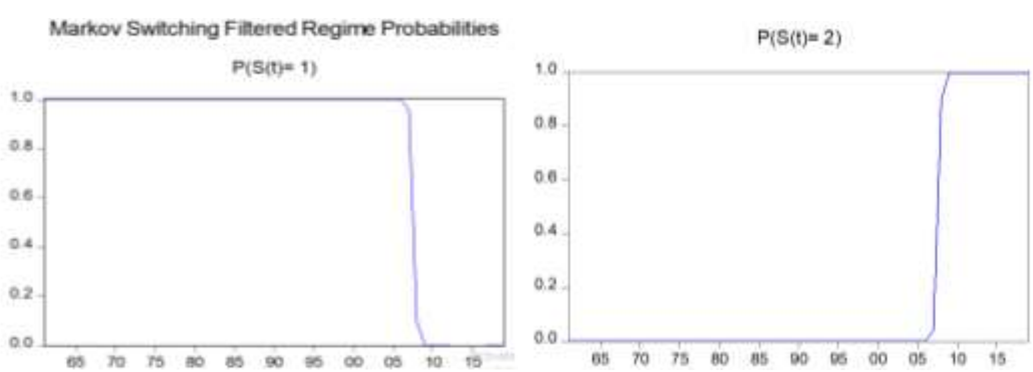

Figure 1 and 2: Chart showing the filtered estimates of the regime probabilities.

Source: Author's computation, 2021.

Interpretation and discussion:

Figures 1 and 2 above is the filtered estimates of the probabilities of been in the two regimes. Filtering is the process by which the probability estimates are updated[7]. This filtering is done to determine the likelihood of the movement from one state to the other and it shows that the states are in the years 2006 and 2009 respectively.

Table 7: Transition Probability and Expected Durations

Transition Probabilities

	1	2
1	0.985513	0.014487
2	0.028554	0.971446

Expected durations:

	1	2
	69.02609	35.02085

Source: Author's computation, 2021.

From table 7, the transition probability is generated from and the time-varying probabilities shows an appreciable state dependence in the transition probabilities with a higher probability of remaining in the origin, $P(S_t = 1/S_{t-1} = 1)$ is 0.985513 for the high output state and $P(S_t = 2/S_{t-1} = 2)$ is 0.971446 for a low output state. The expected durations that corresponds the probabilities in a regime are 69 and 35 respectively, which by implications that inflation on the economic growth will remain in the origin state almost two times before moving to the second state. The result in this study actually supports the result from[6&8]

Conclusions

This study investigated regime switching in the inflation of Nigeria economic growth using the Markov Switching Regression Model. The results from this study indicates that the Markov-Switching Regression model is a high-degree flexible model having captured regime shifts in the mean, variance and the parameters of the vector autoregressive process. Also, it is observed that inflation series is well fitted by the MSVAR model and the filtered probabilities can be deduced. This was accounted for by the estimated parameters and the filtered probability plots of regime 1 and 2. Hence, this study concludes that there is regime switching structure in the dataset.

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