**APPLICATION OF MARKOV-SWITCHING REGRESSION MODEL ON ECONOMIC VARIABLES**

By

1Umeh Edith U. and 2Anazoba Uchenna F

DEPARTMENT OF STATISTICS, NNAMDI AZIKIWE UNIVERSITY, AWKA

editus2002@yahoo.com and eu.umeh@unizik.edu.ng

ABSTRACT

This study investigates the Markov-switching regression model on economic variable using time series data spanning from 1985-2014. The stock data are regime dependent and the two regime multivariate Markov switching vector autoregressive (MSVAR) model is used to examine the structure of the Nigeria stock index prices. It is found that MSVAR model with two regimes detect shifts in the return series and shows evidence of switching in the stock market return series. It is also found that the return series are well fitted by MSVAR model and filtered probabilities can be extracted from the data to evaluate the strength of moving from one state to another. Also, MSVAR model captures the sudden changes in the stock data using exogenous variable which is unobserved and follow a stochastic process. It is recommended that the investors on the stock market should be cautious because the stock market is unstable.

Keywords: Markov-switching regression, Economic variables, Markov-switching vector autoregression, stock price.

**1Umeh Edith U .**DEPARTMENT OF STATISTICS, NNAMDI AZIKIWE UNIVERSITY, AWKA

**editus2002@yahoo.com** **and eu.umeh@**unizik.edu.ng

.

1. **Introduction**

Financial risks, if not well considered, can cause immense damages. Studies show that the stock market involves risks that have lead researchers to investigate methods and techniques to model the risks and fluctuations in the stock market [Suleiman (2011); Ifuero and Asein (2012)]. Financial risks can only be measured using economic variables. According to Kuan (2002), GDP typically fluctuate around a higher level and are more persistent during expansions, but they stay at a relatively lower level and less persistent during contractions It would not be reasonable to expect a single, linear model to capture these distinct behaviors. This has captured the attention of many researchers, thus Krolzig (2003) used Markov-switching vector autoregressive model for the analysis of the Euro-zone business cycle. Ismail and Isa (2008) modeled nonlinear relationship among selected ASIAN stock markets. Olufisayo (2014) examined the relationship between changes in oil prices and stock market in Nigeria.

 In the above literatures; krolzig (2003), did regime inference in MSVAR models using filtering and smoothing, estimated the parameters and of transition probability but he did not find the expected duration of which is done in this paper to know the likely time for the stock data to switch. Ismail and Isa (2008) used MSVAR to model common trend of stock market index from three ASIAN countries where as Olufisayo (2014) used VECM in his work. Ismail and Isa (2008) and Olufisayo (2014) began their studies by describing the data and testing for stationarity using unit root test and stationary test. They used Johansen test to test for cointegration if the data appear stationary. Then, they tested for nonlinearity of the return series of the stock market index. Finally, Ismail and Isa (2008) estimated the MSVAR model and collected series for smoothing probabilities to identify common switching behavior in the series and Olufisayo (2014) used VECM to examine the relationship between changes in oil prices and stock market in Nigeria. But this work use MSVAR to analyze stock market index from NSE. The methodology used in this paper is different in that stability test is conducted on the VAR structure before estimating the MSVAR model and collected series for filtered probabilities to evaluate the strength of moving from one state to another. All these aspects of stock market regime have been largely ignored by existing studies in the case of Nigeria. The focus of this study is to investigate regime switch in the stock market price using the Markov Switching Regression Model.

  **2.0: Methodology**

 **2.1: Type and source of data**

 Time series data on all share index of the Nigerian stock exchange were collected from the Nigerian stock exchange website for this study. The monthly data collected is for a period of 30 years (January 1985 – December 2014) and for a total of 360 observations. This is done; in order to investigate the dynamics (fluctuations) in the Nigeria stock exchange market.

**2.2 Analytical procedure**

The data sourced were analysed using both descriptive and inferential statistics. Descriptive statistics in the form of mean, standard error, sum squared residual, standard deviation were used to summarize the features of the variables under study. Inferential statistics such as Augmented Dickey-Fuller test (ADF) and AR unit root test were employed. The ADF test was used to test for stationarity of the stock price data. AR unit root test was employed to know the stability of the VAR structure to avoid invalid results. The estimation of Markov switching VAR model is done by the maximum likelihood ratio method. The maximum of the likelihood of an MSVAR model results in an iterative process to obtain estimates of autoregressive parameters, the transition probabilities and the expected duration controlled by the unobserved states of a Markov chain.

**2.3 Model specification**

The model of the Augmented Dickey-Fuller can be written as follows:

*Xt* = *ρX*t-1 + *εt*, (2.1)

 If one adds a constant and a trend to the model, the model writes:

 *Xt* = *ρX*t-1 + α + *βt* + *εt*, (2.2)

t = 1, 2...., where the *εt* are independent identically distributed variables that follow a normal distribution; N(0, $σ$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.

 Differencing can be used to make a time series stationary. The differenced series can be written as,

 $y\_{t}^{΄} $ = $y\_{t}$ $-$ $y\_{t-1}$ (2.3)

This is the first difference of y at period t.

 In testing for the unit root in the VAR model, we have to find the modulus of the eigenvalues of the matrix. It follows that the eigenvalues of  are precisely the real numbers  that satisfy the equation

 (2.4)

. If all the unit roots lie inside the unit circle and the modulus is less than one, the VAR structure is stable.

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

 (2.5)

 We may write these probabilities in a transition matrix

 (2.6)

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

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*(*st –* 1 = m|ℑ*t* – 1), the recursion may be broken down into four steps; as in E-views 9:

 $p( s\_{t}$ = $m|$ $J\_{t-1}$) = $\sum\_{j=1}^{M} p( s\_{t} = m| s\_{t-1}=j)$ . $p(s\_{t-1}=j|$ $J\_{t-1}$)

 = $\sum\_{j=1}^{M}p\_{jm}$ ($G\_{t-1}$,$δ\_{j}$). $p(s\_{t-1}=j|$ $J\_{t-1}$) (2.7)

$f(y\_{t},$ $s\_{t}$ = $m|J\_{t-1}$) = $\frac{1}{σ\_{m}}$ ɸ ($\frac{ y\_{t} ̶ μ\_{t} (m) }{σ(m) }$ ) . $p( s\_{t}$ = $ m|$ $J\_{t-1}$) (2.8)

$ L\_{t}$ (β, γ, σ, δ ) = $f(y\_{t},$ $|J\_{t-1}) $ = $\sum\_{j=1}^{M}f( y\_{t}, s\_{t}$ = $j$ $|$ $J\_{t-1}$) (2.9)

 $p(s\_{t}$ = $m$ $ | J\_{t}$ ) = $\frac{f( y\_{t}, s\_{t} = m | J\_{t-1}) }{\sum\_{j=1}^{M}f( y\_{t}, s\_{t} = j | J\_{t-1}) }$ (2.10)

**3. Results and Discussion**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Augmented Dickey-Fuller Unit Root/Stationarity Test** **Hypothesis:** |  |  |  |  |
| H0: There is a unit root in the series. |  |  |
| H1: There is no unit root in the series. The series is stationary. **Table 3.1** |
| Dickey-Fuller test (ADF(stationary) / k: 1 / Stock Exchange Price): | -2.1727 |  |  |
| Tau (Critical value) | -0.9368 |  |  |
| p-value (one-tailed) | 0.5052 |  |  |
| Alpha | 0.05 |  |  |

 **Conclusion:**

As the computed p-value is greater than the significance level (alpha = 0.05), the null hypothesis H0 cannot be rejected, that concludes that there is a unit root in the series. The data is not stationary; therefore the data shall be differenced.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Hypothesis:** |  |  |  |  |  |  |
| H0: There is a unit root in the series. |  |  |  |  |
| H1: There is no unit root in the series. The series is stationary. |  |  |

 **Table 3.2**

|  |
| --- |
| Dickey-Fuller test (ADF(stationary) / k: 1 / Diff1): |
| Tau (Observed value) | -9.9288 |  |  |
| Tau (Critical value) | -0.9124 |  |  |
| p-value (one-tailed) | < 0.0001 |  |  |
| Alpha | 0.05 |  |  |

**Conclusion:**

As the computed p-value is lower than the significance level (alpha = 0.05), the null hypothesis H0 is rejected, accept the alternative hypothesis H1 that there is no unit root in the series. The series is stationary.

 **Vector Autoregressive Estimation**

 

Fig.3.1: Graph showing Inverse Roots of VAR structure.

Since no root lies outside the unit circle and the modulus is less than one, VAR satisfies the stability condition.

**Markov-switching Regression Analysis**

**Table 3.3 Results of the analysis**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Coefficient |  Std. Error | z-Statistic | Prob.   |
|  |  |  |  |  |
|  |  |  |  |  |
| **Regime 1** |
|  |  |  |  |  |
|  |  |  |  |  |
| C | 29.65635 | 137.5556 | 0.215595 | 0.8293 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Regime 2** |
|  |  |  |  |  |
|  |  |  |  |  |
| C | 11001.54 | 851.1930 | 12.92485 | 0.0000 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Common coefficients** |
|  |  |  |  |  |
|  |   |  |  |  |
| AR(1) | 0.206507 | 0.050999 | 4.049275 | 0.0001 |
| AR(2) | 0.310993 | 0.051094 | 6.086679 | 0.0000 |
| LOG(SIGMA) | 7.134001 | 0.037689 | 189.2863 | 0.0000 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Table 3.4 Transition Matrix Parameters** |
|  |  |  |  |  |
|  |  |  |  |  |
| P11-C | 5.179004 | 0.716148 | 7.231750 | 0.0000 |
| P21-C | 8.956865 | 62.86110 | 0.142487 | 0.8867 |
|  |  |  |  |  |
|  |  |  Table 3.5 Descriptive s |  |  |
| Mean dependent var | 96.22813 |     S.D. dependent var | 1562.039 |
| S.E. of regression | 1465.945 |     Sum squared resid | 7.61E+08 |
| Durbin-Watson stat | 2.306951 |     Log likelihood | -3082.869 |
| Akaike info criterion | 17.21376 |     Schwarz criterion | 17.28948 |
| Hannan-Quinn criter. | 17.24387 |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| Inverted AR Roots |      0 .67 |          -0.46 |  |
|  |  |  |  |  |
|  |  |  |  |  |

Source: Authors computation.

 We see, from the upper part of table 3.3 the differences in the regime specific means (Regime 1: 29.65635, Regime 2: 11001.54), what Hamilton (1990) termed the fast and slow (in this case, the slow and fast) growth rates for the Nigeria stock market price for the period under study (1985 – 2014). We can also observe that regime 2 is significant (p<0.05), while regime 1 is not (p>0.05). This implies that the dynamics in the first regime is not substantial.

The bottom section of table 3.4 shows the standard descriptive statistics for the equation. The unit roots are 0.67 and -0.46 which are real roots which means that they do not appear in conjugate pairs, they are roots on x-axis.

 **Estimation Equation:**

1: Diff = 29.6563463707 + [AR(1)=0.20650713911, AR(2)=0.310992536816]

2: Diff = 11001.5405593 + [AR(1)=0.20650713911, AR(2)=0.310992536816]

Where

 Diff = Differenced Data

**Table 3.5**

**Transition Probability**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  |  |  |  |
|  |  |  1 |  2 |
|  |  1 | 0.994398 | 0.005602 |
|  |  2 | 0.999871 | 0.000129 |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| **Expected durations:** |  |
|  |  |  1 |  2 |
|  |  | 178.5060 | 1.000129 |
|  |  |  |  |
|  |  |  |  |

Here, we see the transition probability matrix and the expected durations. This shows considerable state dependence in the transition probabilities with a relatively higher probability of remaining in the origin regime (0.994398 for the high output state, 0.000129 for the low output state). The corresponding expected durations in a regime are approximately 178.5 and 1.0 quarters, respectively, which imply that the stock market will remain in the origin state for a very long time before moving to the second state.



 Fig. 3.2: Chart showing the filtered estimates of the regime probabilities.

Fig. 3.2 displays the filtered estimates of the probabilities of being in the two regimes. Filtering is the process by which the probability estimates are updated. This is done in order to determine the likelihood of moving from one state to the other. This shows that the states are in the years 2008 and 2009.

**4. CONCLUSION**

This study aimed at investigating regime switching in the stock market price using the Markov Switching Regression Model. Based on the results obtained from all the analyses, it concludes as follows; firstly, the study conclude that the Markov-Switching Regression model is a high-degree flexible model because it can capture regime shifts in the mean, in the variance and also the parameters of the vector autoregressive process. Secondly, it is found that the return series are well fitted by the MSVAR model and the filtered probabilities can be extracted. This is shown by the estimated parameters and the filtered probability plots of regime 1 and 2. Finally, it concludes that there is regime switching structure in the series.

**Reference**

Hamilton .J.D (1989). The dynamics of GNP growth rates.

Ifuero .O.O and Asein .I.E (2012). Market Risk and Returns: Evidence from the Nigerian capital market, Asian Journal of Business Management 4(4): 367-372.

Ismail .M.T. and Isa .Z.B. (2008). Modelling nonlinear relationship among selected ASEAN stock markets. Journal of Data science, 533-545.

 Krolzig, Hanns-Martin (2003), Construction of turning point chronologies with Markov-switching autoregressive models: the Euro-zone business cycle. Department of Economics and Nuffield College, Oxford University.

Kuan Chung-Ming (2002), Lecture on the Markov Switching Models, institute of Economics, Academia Sinica, Taipei, 115, Taiwan. www.sinica.edu.tw/as/ssrc/ckuan

Nigeria stock exchange website.

 Olufisayo .A.O. (2014). The relationship between changes in oil prices and stock market in Nigeria. European Journal of Sustainable Development, 3,2 ,33-40.

Suleiman .H.K.(2011). “ Stock Return and the Volatility Persistence in the Nigerian Capital Market” being a Seminal Paper submitted to the Department of Accounting, Ahmed Bello University, Zaria. PHD thesis.