# Detecting Structural Breaks in Some Major Macroeconomic Variables in Ghana

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**Abstract**

This research was conducted to detect structural breaks in some major macroeconomic variables using single and multiple breaks approaches. The data used was obtained from the Central Bank of Ghana (BoG) and included monthly Consumer Price Index (CPI), 91-day Treasury bill (91 T-bill), Inflation rate, Cocoa Price (Cocoa P) and Crude Oil Price (Crude oil P) spanning from January, 2007 to December, 2012. The study showed that all the macroeconomic variables were not normally distributed as they were platykurtic in nature with their standard deviations far from their means, indicating volatility. Using ADF test, all the variables were not stationary at level, but stationary after first differencing. The Chow, Quandt Likelihood, Cumulative Sum test (CUSUM), Cumulative Sum Squared test (CUSUMSQ) and Bai and Perron multiple tests were used to check for structural breaks. They all showed structural breaks in all the variables. The observed variables were categorized into subgroups with smaller sizes of 72, 24, 12 and 6 months. The number of breakpoints detected by the Bai and Perron multiple tests were six (6) in all the macroeconomic variables and in each subgroup too. Detected breaks date from the CUSUM test were substituted into the Chow test and there were inconsistencies.

**Keywords:** structural breaks, macroeconomic variables, stationary

## 1. Introduction

The effect of a sudden or an unexpected change in the trend of an economic time series, structural break, has been a major concern especially to economic researchers, investors and policy makers.

The finding that there are structural breaks in key macroeconomic variables should be taken into account in econometric modeling and forecasting; otherwise, ignoring them can lead to model misspecification and spurious results of model parameters.

According to Perron, (1989) and Alagidede, Coleman and Cuestas (2010), unit root tests may suffer from power problems when there are structural breaks in the data generation process. This often would lead to incorrect prediction of the series in terms of the order of integration, when infact it is stationary around a broken or shifting drift (Agyapong and Anokye, 2012).

Abbas et al., (2008) employs all available annual time series data to endogenously determine the timing of structural breaks for 10 macroeconomic variables in the Australian economy. The ADF (Augmented Dickey and Fuller) test and the LP (Lumsdaine and Papell, 1997) test are used to examine the time series properties of the data. The ADF test results provide no evidence against the unit root null hypothesis in all ten macroeconomic variables. After accounting for the two most significant structural breaks in the data impacting on both the intercept and trend, the results from the LP test indicated that the null of at least one unit root is rejected for four of the variables under investigation at the 10 per cent level or better. They also found that the dates of structural breaks in wages shock occurring in 1973 to 1975 period, having recession between the period 1990 to 1991, the culmination of financial deregulation and innovation in the late 1980s; and the 1997 Asian crisis( Abbas et al.,2008).

Waheed et al.,(2006) examine eleven Pakistani macroeconomic series using annual data and Andrews test identifies endogenously the point of the single most significant structural break in every time series examined. The results showed that ten of the eleven series studied bear witness to the presence of a structural break during the period 1972 to 1976 (Waheed et al., 2006).

Mathew P. Hitt investigate the Bai and Perron (BP) technique more thoroughly, specifically, he explore its accuracy over a full range of persistence levels in simulated data. When the data are even moderately autocorrelated, he criticizes the BP technique (as implemented for R by Zeleis et al., 2003) that frequently selects "optimal" segmentations containing one or more structural breaks for data which contain no such break. Further, the technique tends to overestimate the number of breaks in data simulated to contain just one structural break. (Matthew P. Hitt, 2013).

Although many of these researches have been carried out all over the world, Ghana being a developing country little has been done. Hence, this study further seeks to detect structural breaks in some major macroeconomic variables in Ghana.

## 2.0 MATERIALS AND METHODS

The sample data for this study was obtained from the Central Bank of Ghana (BoG) spanning from January, 2007 to December, 2012. The data was a monthly data comprising the following major macroeconomic variables; Consumer Price Index (CPI), 91-day Treasury bill (91 T-bill), Inflation rate, Cocoa Price (Cocoa P) and Crude Oil Price (Crude oil P). To ascertain the true nature of the data, we carried out some preliminary tests. This included a unit root test to establish the stationarity of the time series data used. The Augmented Dickey-Fuller (ADF) test was used.

### 2.1 Augmented Dickey-Fuller (ADF) test

This was used to test for the stationarity of the time series. Establishing this would help avoid spurious regression in fitting. This test was carried out by fitting three different models; without constant, with constant and with constant and trend. ADF test is based on the assumption that a time series data $y_t$ follows a random walk given by,

$$y_t = \rho y_{t-1} + \epsilon_t \dots\dots\dots\dots\dots (1)$$

Subtracting $y_{t-1}$ from both sides in equation (1) above gives

$$\Delta y_t = \beta y_{t-1} + \epsilon_t \dots\dots\dots \qquad (2)$$

where $\Delta y_t = y_t - y_{t-1}$ and $\beta = \rho - 1$.

The null hypothesis is $H_0: \beta = 0$, that is $\rho = 1$, against the alternative given by $H_1: \beta < 0$, that is $\rho < 1$. The ADF test was carried out at 5% level of significance. The various tests used to obtain the main results of the study are Chow, Quandt Likelihood ratio and Cumulative Sum tests.

### 2.2 Chow Test

This test offers a classical possibility for testing structural change. Different variants are often reported: sample-split, break-point, and forecast tests. The Chow test is a statistical and econometric test which determines whether the coefficients in two linear regressions on different datasets are equal. In time series analysis, it is used to test for structural breaks. The test statistic is given as

$$\frac{\left(\boldsymbol{S_C} - (\boldsymbol{S_1} + \boldsymbol{S_C})\right)/(\boldsymbol{k})}{(\boldsymbol{S_1} + \boldsymbol{S_2})/(\boldsymbol{N_1} + \boldsymbol{N_2} - \boldsymbol{2k})} \dots\dots..(\mathbf{3})$$

where

$S_C$ is the sum of squared residuals from the combined data, $S_1$ is the sum of squared residuals from the first group, $S_2$ is the sum of squared residuals from the second group,

$N_1$ and $N_2$ are the number of observations in each group and k is the total number of parameters.

### 2.3 Quandt Likelihood Ratio test

This test is a modified version of the chow test which identifies the maximum break date at unknown date or endogenous. The null hypothesis is that there is no break at the unknown date whilst the alternative is that there is break at the unknown date. The statistic does not follow the standard F distribution and the critical values are from Stock and Watson (2003).

**2.4 Cumulative Sum Test:** This is a regression analysis technique and is defined as

$$y_t = x_t' \beta_t + \mu_t, \qquad t = 1, \dots, T, \dots..(4)$$

where $y_t$ is the observation at time *t* and $x_t$ is a vector of observations on *k* regressors. The cumulative sum of recursive residuals, denoted CUSUM, is defined by

$$\mathrm{CUSUM} = \frac{1}{\hat{\sigma}} \sum_{j=k+1}^{t} w_t \dots\dots\dots.(5)$$

where

$$\hat{\sigma}^2 = \frac{1}{n-k} \sum_{t=k+1}^{n} w_t^2$$

and

$$w_r = \frac{y_r - x_r' b_{r-1}}{\sqrt{(1 + x_r'(X_{r-1}' X_{r-1})^{-1} x_r)}},$$

$t = k+1, \dots, T$, where $b_r = (X_r' X_r)^{-1} X_r' Y_r$, and the matrix $X_r' X_r$ is assumed be non-singular. Also, $X_{r-1}' = [x_{1,} \dots, x_{r-1}]$ and $Y_r' = [y_{1,} \dots, y_r]$.

The CUSUM has mean zero and a constant variance. It can also reveal structural changes and therefore often plotted for $t = k+1, \dots, T$ in checking the model. We require a method for testing the significance of the departure of the sample path of the CUSUM from its mean value, 0. Brown *et. al.* (1975) used the method of finding a pair of lines lying symmetrically above and below the line 0, such that the probability of crossing one or both lines is the required level of confidence. If the CUSUM wanders off too far from the zero line, this is evidence against structural stability of the underlying model.

### 2.5 Bai and Perron test

Bai and Perron (2003a) discuss a method based on a dynamic programming algorithm that is very efficient. Indeed, the additional computing time needed to estimate more than two break dates is marginal compared to the time needed to estimate a two break model. The basis of the method, for specialized cases, is not new and was considered by Guthery (1974), Bellman and Roth (1969) and Fisher (1958). A comprehensive treatment was also presented in Hawkins (1976). The main framework of analysis can be described by the following multiple linear regression with m breaks (or m + 1 regimes)

$$y_t = x_t'\beta + z_t'\delta_j + \mu_t \qquad (6)$$

$t = T_{j-1} + 1, \ldots, T_j$ , for $j = 1, \ldots, m + 1$.

In this model, $y_t$ is the observed dependent variable at time $t$; both $X_t$ (p x 1) and $Z_t$ (p x 1) are vectors of covariates and $\beta$ and $\delta_j (j = 1, \ldots, m + 1)$ are the corresponding vectors of coefficients; $\mu_t$ is the disturbance at time t. The indices $(T_1, \ldots, T_m)$ or the break points, are explicitly treated as unknown (the convention that $T_0 = 0$ and $T_{m+1} = T$ is used). The purpose is to estimate the unknown regression coefficients together with the break points when T observations on $(y_t, x_t, z_t)$ are available.

## 3.0 RESULTS

The macroeconomic variables for the entire period were positively skewed and leptokurtic in nature with the exception of Consumer Price Index (CPI) and Cocoa Prices as shown in Table 1. The results from Table 2 and 3 showed that all the series were stationary at level. Thus non-stationary at 5% level of confidence and after first differencing, all the series became stationary using ADF test with constant, without constant and with constant and trend.

Using Chow, Quandt and CUSUM tests, all the series showed structural break at various points. The variables were categorized into subgroups with smaller sizes of 72, 24, 12 and 6 months. Table 4 showed the detection of structural break for a 72 month observation. The Chow test indicated that p-values were less than the significant level of 5% for the variables except Treasury bill (T-bill) which has a p-value of 0.107. Thus there was a structural break observed on 2009:12 which meant that the co-efficient of regression were not the same across the time period, except Treasury bill.

The Quandt Likelihood ratio from Table 4 showed that there were structural breaks in all the variables. Since the various variables test statistic were greater than the critical value, we reject the null hypothesis and conclude that there were structural breaks. Thus the parameters were not the same across the time period. CUSUM test shown in Table 4 indicated the p-value to be zero and is less than the 5% significant level. We reject the null hypothesis and conclude that there was no break in the series except Inflation rate. The Cumulative sum squared test confirmed that there were structural breaks in the inflation as shown in figures 1 and 2.

It was observed that the size of data was very important in detecting structural breaks; the larger the size, the higher the precision of detection using the single breaks methods. The power of CUSUM test decreases as the size of the data decreases as shown in Table 4-7. CUSUM test could not detect any break in the six months observation.

Bai and Perron multiple tests showed six (6) breakpoints in all the variables as shown from figures 3 -8 and the same number of breaks was observed in each subgroup.

Table 8 showed detected breaks date from the CUSUM test that were substituted into the Chow test and there were inconsistencies.

## 4.0 CONCLUSION

This study investigates structural breaks in major macroeconomic variables in Ghana; CPI, 91 Treasury bill, Inflation Rate, Cocoa and Crude oil. Preliminary analysis revealed that all the variables under consideration were not stationary, but stationary after first differencing, hence integrated of order one. Also, the distributions of the variables were platykurtic. The Chow, Quandt Likelihood, Cumulative Sum test (CUSUM), Cumulative Sum Squared test (CUSUMSQ) and Bai and Perron multiple tests were used to check for structural breaks. They all showed structural breaks in all the variables. The Cumulative sum squared test confirmed the CUSUM test that there were structural breaks in the variables. The observed variables were categorized into subgroups with smaller sizes of 72, 24, 12 and 6 months. The number of breakpoints detected by the Bai and Perron multiple tests were six (6) for all the macroeconomic variables and in each subgroup too. The power of CUSUM test decreases as the size of the data decreases. Detected breaks date from the CUSUM test were substituted into the Chow test and there were inconsistencies.

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## Notes

**Table1:** Descriptive statistics of macroeconomic variables

| Description | CPI | 91Tbill | Inflation rates | Cocoa (US$/tonne) | Crude oil (US$/Barrel) |
|---|---|---|---|---|---|
| **Minimum** | 206.080 | 9.250 | 8.390 | 1613.000 | 630.610 |
| **Maximum** | 412.430 | 25.600 | 20.740 | 3430.000 | 1770.130 |
| **Mean** | 313.196 | 16.141 | 12.527 | 2575.331 | 1167.218 |
| **Std. Dev** | 63.325 | 6.239 | 4.209 | 453.449 | 370.761 |
| **CV*** | 0.202 | 0.387 | 0.336 | 0.176 | 0.318 |
| **Skewness** | -0.173 | 0.455 | 0.778 | -0.145 | 0.259 |
| **Kurtosis** | -1.237 | -1.551 | -0.990 | -0.863 | -1.361 |

*CV stands for coefficient of variation

**Table 2:** ADF test at level

| | Without constant | | With constant | | Constant and Trend | |
|---|---|---|---|---|---|---|
| **Variable** | **Test statistic** | ***p*-value** | **Test statistic** | ***p*-value** | **Test statistic** | ***p*-value** |
| **CPI** | 5.766 | 1.000 | -1.084 | 0.7181 | -1.354 | 0.866 |
| **91 T bill** | 0.744 | 0.873 | -0.862 | 0.795 | -0.867 | 0.954 |
| **Inflation rate** | -0.482 | 0.504 | -0.417 | 0.900 | -1.353 | 0.866 |
| **Cocoa Price** | 0.137 | 0.723 | -2.306 | 0.173 | -1.850 | 0.670 |
| **Crude oil Price** | 2.173 | 0.993 | -0.648 | 0.852 | -2.153 | 0.508 |

**Table 3:** ADF test of variables after first differencing

| | Without constant | | With constant | | Constant and Trend | |
|---|---|---|---|---|---|---|
| **Variable** | **Test statistic** | ***p*-value** | **Test statistic** | ***p*-value** | **Test statistic** | ***p*-value** |
| **CPI** | -2.518 | 0.012 | -6.509 | 6.485e-009 | -6.530 | 5.089e-008 |
| **91 T bill** | -4.566 | 1.391e-005 | -3.407 | 0.011 | -3.381 | 0.044 |
| **Inflation rate** | -3.948 | 0.000 | -3.468 | 0.009 | -3.632 | 0.027 |
| **Cocoa Price** | -7.037 | 4.055e-013 | -5.464 | 2.102e-006 | -5.582 | 1.1e-005 |
| **Crude oil Price** | -7.334 | 9.357e-015 | -5.975 | 1.374e-007 | -5.920 | 1.814e-006 |

**Table 4:** Detecting structural break in 72 Months observation

| Test | | CPI | 91 T bill | Inflation rate | Cocoa Price | Crude oil Price |
|---|---|---|---|---|---|---|
| | **Test statistic** | 98.800 | 2.306 | 31.016 | 8.399 | 111.395 |
| **Chow** | **Split date** | 2009:12 | 2009:12 | 2009:12 | 2009:12 | 2009:12 |
| | **p-value** | 0.000* | 0.107 | 0.000* | 0.001* | 0.000* |
| | **Test statistic** | 111.092 | 11.252 | 42.758 | 33.509 | 136.838 |
| **Quandt** | **Break date** | 2009:05 | 2008:05 | 2010:04 | 2008:02 | 2010:09 |
| | **Critical value (1%)** | 7.780* | 7.7800* | 7.7800* | 7.7800* | 7.780* |
| | **Test statistic** | 14.154 | 2.185 | -1.333 | 5.326 | 11.079 |
| **CUSUM** | **Break date** | 2009:03 | 2009:01 | 2009:01 | 2008:08 | 2010:01 |
| | **p-value** | 0.000 | 0.032 | 0.187* | 0.000 | 0.000 |

NB: *indicate a break.

**Table 5:** Detecting structural break in a 24 Months observation

| **Test** | | **CPI** | **91Tbill** | **Inflation rate** | **Cocoa Price** | **Crude oil Price** |
|---|---|---|---|---|---|---|
| | **Test statistic** | 38.158 | 14.257 | 36.986 | 21.762 | 100.85 |
| **Chow** | **Split date** | 2007:12 | 2007:12 | 2007:12 | 2007:12 | 2007:12 |
| | **p-value** | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| | **Test statistic** | 277.842 | 147.220 | 99.730 | 30.270 | 127.065 |
| **Quandt** | **Break date** | 2008:01 | 2008:05 | 2008:01 | 2008:02 | 2007:11 |
| | **Critical value (1%)** | 7.780* | 7.780* | 7.780* | 7.780* | 7.780* |
| | **Test statistic** | 4.421 | 3.682 | 4.948 | 2.938 | 3.822 |
| **CUSUM** | **Break date** | 2007:10 | 2007:10 | 2007:10 | 2007:10 | 2007:10 |
| | **p-value** | 0.000* | 0.001* | 0.000* | 0.008* | 0.001* |

NB: *indicate a break.

**Table 6:** Detecting structural break in 12 Months observation

| **Test** | | CPI | 91Tbill | Inflation rate | Cocoa Price | Crude oil Price |
|---|---|---|---|---|---|---|
| | **Test statistic** | 5.862 | 9.317 | 1.837 | 2.686 | 13.290 |
| **Chow** | **Split date** | 2007:06 | 2007:06 | 2007:06 | 2007:06 | 2007:06 |
| | **p-value** | 0.027* | 0.008* | 0.220 | 0.128 | 0.252 |
| | **Test statistic** | 11.032 | 30.945 | 26.310 | 18.500 | 21.524 |
| **Quandt** | **Break date** | 2007:09 | 2007:10 | 2007:10 | 2007:08 | 2007:09 |
| | **Critical value (1%)** | 7.780* | 7.780* | 7.780* | 7.780* | 7.780* |
| | **Test statistic** | -1.970 | 3.167 | 1.495 | -2.219 | 1.224 |
| **CUSUM** | **Break date** | No date | 2007:11 | No date | 2007:10 | No date |
| | **p-value** | 0.080 | 0.011 | 0.169 | 0.054 | 0.252 |

NB: *indicate a break.

**Table 7:** Detecting structural break in 6 Months observation

| **Test** | | **CPI** | **91Tbill** | **Inflation rate** | **Cocoa** | **Crude oil** |
|---|---|---|---|---|---|---|
| | **Test statistic** | 0.103 | 153.802 | 1.852 | 18.493 | 1.583 |
| **Chow** | **Split date** | 2007:03 | 2007:03 | 2007:03 | 2007:03 | 2007:03 |
| | **p-value** | 0.907 | 0.006* | 0.351 | 0.051 | 0.387 |
| | **Test statistic** | 7.392 | 1.000 | 3.825 | 1.00 | 1.00 |
| **Quandt** | **Break date** | 2007:05 | 2007:01 | 2007:02 | 2007:01 | 2007:01 |
| | **Critical value (1%)** | 7.120* | 12.600 | 7.120 | 12.160 | 12.160 |
| | **Test statistic** | 0.465 | 3.457 | 1.966 | -1.994 | -2.472 |
| **CUSUM** | **Break date** | No date | No date | No date | 2007:03 | No date |
| | **p-value** | 0.674 | 0.041* | 0.144 | 0.140 | 0.090 |

NB: *indicate a break.

**Figure 1: CUSUM plot for Inflation rate**

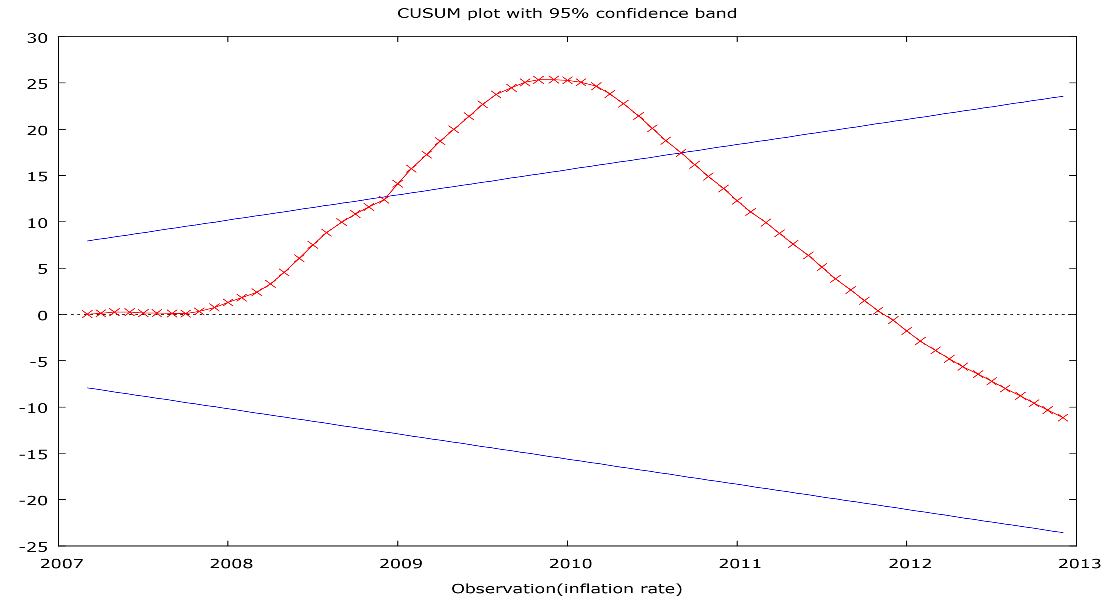


**Figure 2:** CUSUMSQ plot for Inflation rate

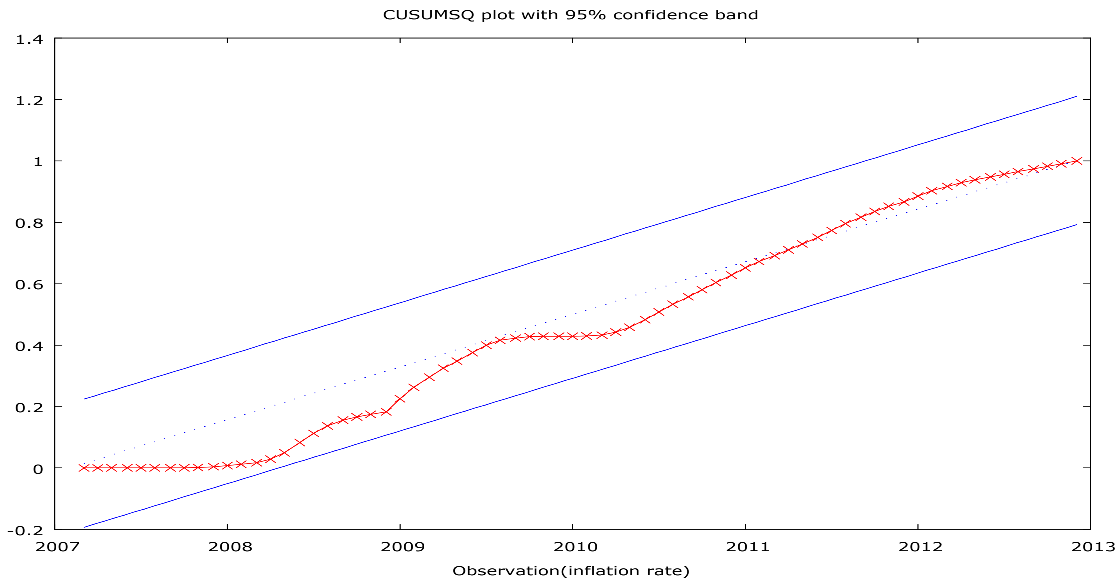


**Table 8:** Inconsistency among the methods

| **CUSUM Test** | **Chow Test** | **Remarks** |
|---|---|---|
| 2008:07 | 2008:07 | No break |
| 2008:08 | 2008:08 | No break |
| 2008:09 | 2008:09 | Break |
| 2008:11 | 2008:11 | Break |
| 2007:08 | 2007:08 | Break |
| 2008:12 | 2008:12 | Break |
| 2009:01 | 2009:01 | Break |

 

**Table 9:** Detecting structural break in 12 Months observation

| Type of test | CPI | Treasury bill | Inflation rate | Cocoa | Crude oil |
|---|---|---|---|---|---|
| **Chow test** | 5.86207 | 9.31646 | 1.83731 | 2.68644 | 13.2906 |
| **Split date** | 2007:06 | 2007:06 | 2007:06 | 2007:06 | 2007:06 |
| **p − value** | 0.0270 | 0.0081 | 0.2204 | 0.1280 | 0.2520 |
| **Quandt test** | 11.0321 | 30.9452 | 26.3102 | 18.5 | 21.5239 |
| **Break date** | 2007:09 | 2007:10 | 2007:10 | 2007:08 | 2007:09 |
| **Critical value (1%)** | 7.78 | 7.78 | 7.78 | 7.78 | 7.78 |
| **CUSUM** | -1.97019 | 3.16732 | 1.49479 | -2.2192 | 1.22404 |
| **Break date** | No date | 2007:11 | No date | 2007:10 | No date |
| **p − value** | 0.0803 | 0.0114 | 0.1691 | 0.0536 | 0.2520 |

**Figure 3:** Multiple break in 12 Months observation CPI

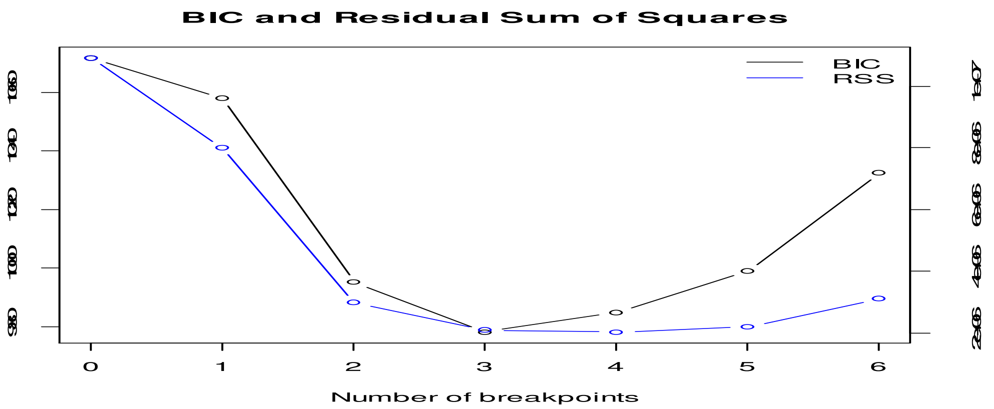


**Figure 4:** Multiple break in 12 Months observation Treasury bill

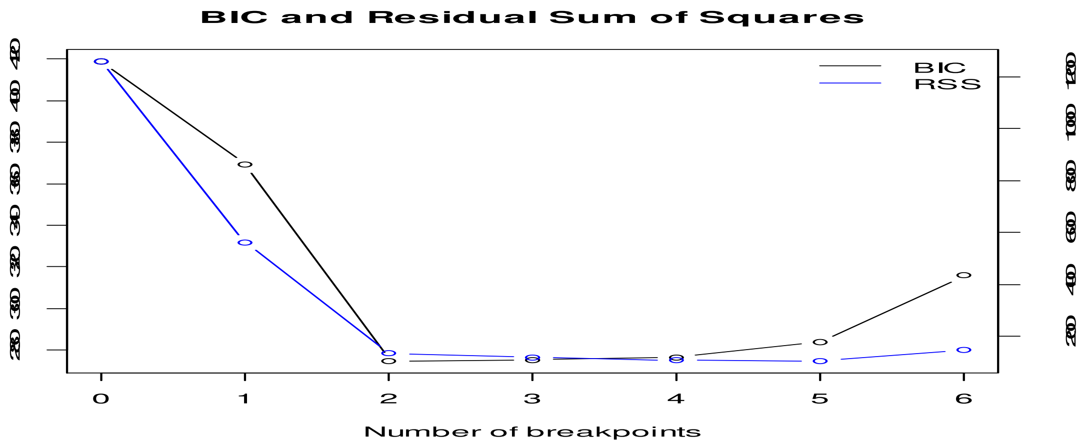


**Figure 5:** Multiple break in 12 Months observation Inflation rate

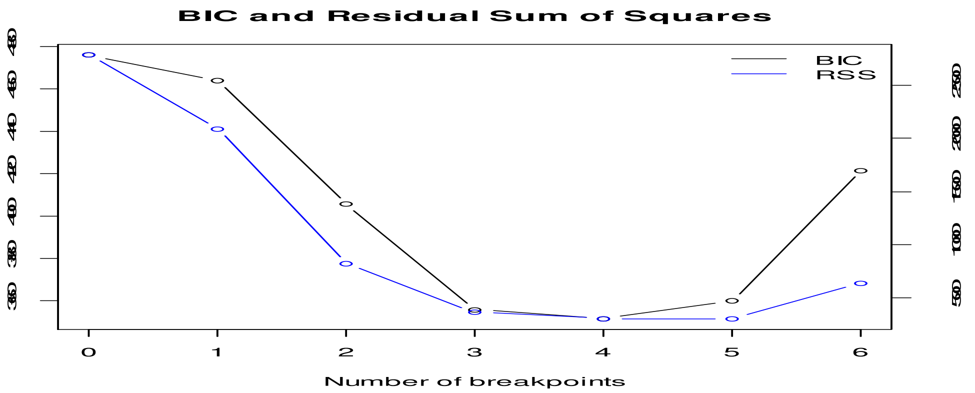

**Figure 6:** Multiple break in 12 Months observation Cocoa

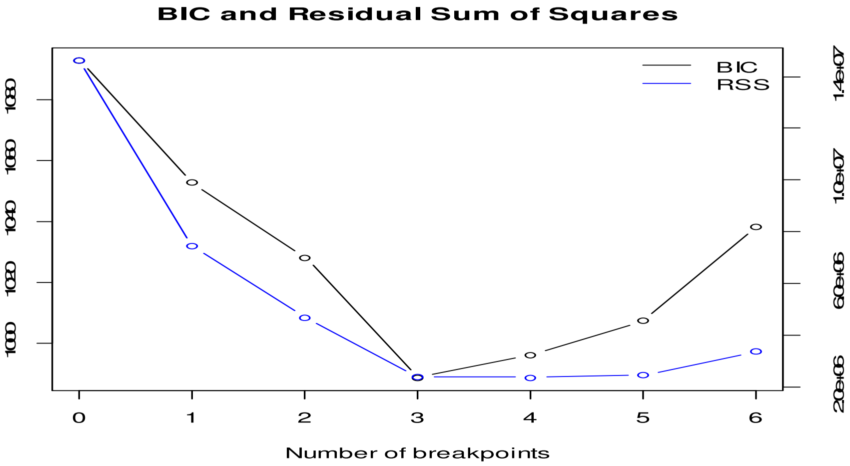


**Figure 7:** Multiple break in 12 Months observation Crude oil