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Abstract:

Purpose: By empirically examining Zambia's CPI between 2010 and 2020, the study attempts to determine the structural change in the time series. The CPI is one of the most important variables for analyzing inflation in macroeconomics, therefore any change in the dynamic must be determined. In this paper change points and dates are highlighted and statistical analysis methods have been employed to explore and discover the underlying patterns and trends of Zambia's CPI for the past 10 years.

Methodology/approach: Secondary Data from Zambia Statistics Agency (ZamStats.gov.zm) was used for the Study. From 132 elements of observations of time series for 10 years, the detection methods of structural change were employed. The Cumulative Sum Tests (CUSUM test) of Ordinary Least Squares (OLS), Andrew Sup F test, Bai and Perron test, and Chow test were used to detect the model stability and verify the hypothesis using P-value.

Results: The results show that there were five (5) Structural changes or breaks in mean and variance and these were February 2012, February 2014, October 2015, October 2017, and May 2019. The structural breaks are highly suggestive as they appear to broadly coincide with readily identifiable macroeconomic events, increased stock of external debt following the issuance of Eurobonds in 2012, 2014, and 2015, rise increased food prices arising from the adverse impact of erratic rainfall on agricultural output and the pass-through from the depreciation of the Kwacha.

Policy Implication: Based on the study, strong and sound macroeconomic policies are needed to be implemented: Such as debt management and diversification of foreign exchange sources, and increased earnings.

Keywords: *CUSUM, Bai Perron, Chow's test, Structural break, Consumer Price index (CPI).*

1. INTRODUCTION

1.1 Background

A structural break is a sudden shift in a time series of data. This change could involve a change in the mean or change in other parameters of the process that produce the series. In economics and statistics, the structural break is a very critical part to take note of because of its nature of unexpected change over time in the parameters of regression models. These unexpected can lead to huge forecasting errors and instability of the model in general. Hendry (2001), states that lack of stability of coefficients frequently caused forecast failure, and therefore, we routinely test for structural stability i.e. time-invariance of regression coefficients.

Detecting such changes is important in many different application areas. Moreover, the longer the data period used to estimate the data generating process the more likely that structural breaks occur. According to Timmermann 2001, what distinguishes a break from a shock is that, although both are low-frequency events, the former has a long-run (persistent) effect.

Tests for parameter instability and structural change in regression models have been a significant part of applied econometric work dating back to Chow (1960), who tested for regime change at a priori known date using an F-statistic. Giacomini and Rossi, (2009) state that testing for structural breaks is a rich area of research and there is no one-size-fits-all test for structural breaks. Thus, which test to implement depends on several factors such as is the break date known or unknown also if there is a single break or multiple breaks. Therefore, knowing the statistical characteristics of both the breaks and data helps to ensure that the correct test is implemented.

Valentinyi, (2004) defines Structural break, as instability or break in the parameters of the data generation process (or in the forecasting model). It can occur due to a change in the intercepts (level), in the slope parameter, or the volatility of the error term. Killick and Idris (2014) state that a change point is a name given to the problem of estimating the point at which the statistical properties of a sequence of observations change.

Zeileis (2005), notes that structural break tests can be divided into three main classifications: The first classification is the “residual-based test” or “fluctuation test”. These tests most especially comprise the initial CUSUM test (Brown et al, 1975) and its improvements (Ploberger and Krämer 1992). The second classification of tests builds on the traditional exogenous structural break tests, like the F test that has been proposed by Chow (1960) for this purpose. To detect the most likely break point, these tests use the supremum of the F statistic. However, the more recent forms of this test use upgraded statistics to test whether the null hypothesis of a constant parameter regime should be rejected. We examine both, the original version of the test proposed by Andrews (1993) and the refinements proposed by Andrews et al, (1996). The third category of tests is based on Maximum likelihood test scores. The first test of this kind has been developed by Nyblom (1989) for nonlinear models.

Time series data has several characteristics that make it unique, and each observation is expected to depend on past observations. However, when you fit a time series regression, it is always assumed that the coefficients are stable over time. Being able to detect when the structure of the time series changes can give us insights into the problem we are studying. Structural break tests enable us to determine when and whether there is a significant adjustment in data.

Since public spending and consumption structural breaks are key for determining and constructing estimations and predictions, this paper attempts to fill up the gap in the empirical literature on the stability test and breakpoint, detection of goods and service consumption such as Consumer Price

Index (CPI) which uses time series. The tests considered in this study are applied to test for structural breaks in the parameter regime of a standard linear model.

The paper outlines three sections, the first part is testing the changes in the mean within the structural break. The second part looks for the presence of a break in the series using CUSUM tests of OLS and brings to light the unknown break dates and points. The last part is testing the hypothesis using Chow's test, thereafter stating structural dates and the number of breakpoints within the system, using R software packages.

2.0 Methodology

This study considers structural break in the time series model using Zambia's Consumer Price Index (CPI) for 10 years. The data used in this study is secondary and was obtained from Zambia Statistics Agency (www.zamstat.gov.zm).

Model

We consider the standard model of linear regression

$y_i = X_i^T \beta_i + \mu_i$ (i=1……n)

Where at the time i, y_i is the observation of the dependent variable, $x_i = (1, x_i \ldots \ldots \ldots x_{ik})^T$ is a k × 1

Vector of observations of the independent variables, with the first component equal to unity, μ_i

are iid $(0, \sigma^2)$, and βi is the k × 1 vector of regression coefficients. Tests on structural change are

Premised on analyzing the null hypothesis of "no structural change"

$\beta_0 : \ \beta_1 = \beta_0$ (i = 1, . . . , n)

contrary to the alternative hypothesis that the coefficient vector varies over time, with certain tests being more or less suitable (i.e., having good or poor power) for certain patterns of deviation from the null hypothesis.

2.1 Empirical Analysis of the data

The data summary of the time series

head(df)			tail(df)		
1	2010/01/01	105.01	127	2020/07/01	265.83
2	2010/02/01	105.47	128	2020/08/01	267.07
3	2010/03/01	106.55	129	2020/09/01	270.81
4	2010/04/01	107.48	130	2020/10/01	274.20
5	2010/05/01	107.74	131	2020/11/01	280.21
6	2010/06/01	107.93	132	2020/12/01	289.04

Summary Table 1.

Central Tendency of the Series	
Length:132	Min. :105.0
Class: character	1st Qu.:124.8
Mode: character	Median :152.1
	Mean : 169.1
	3rd Qu.:207.9
	Max. :289.0

Summary Table 2.

Zambia's Consumer Price Index (CPI) for 10 years

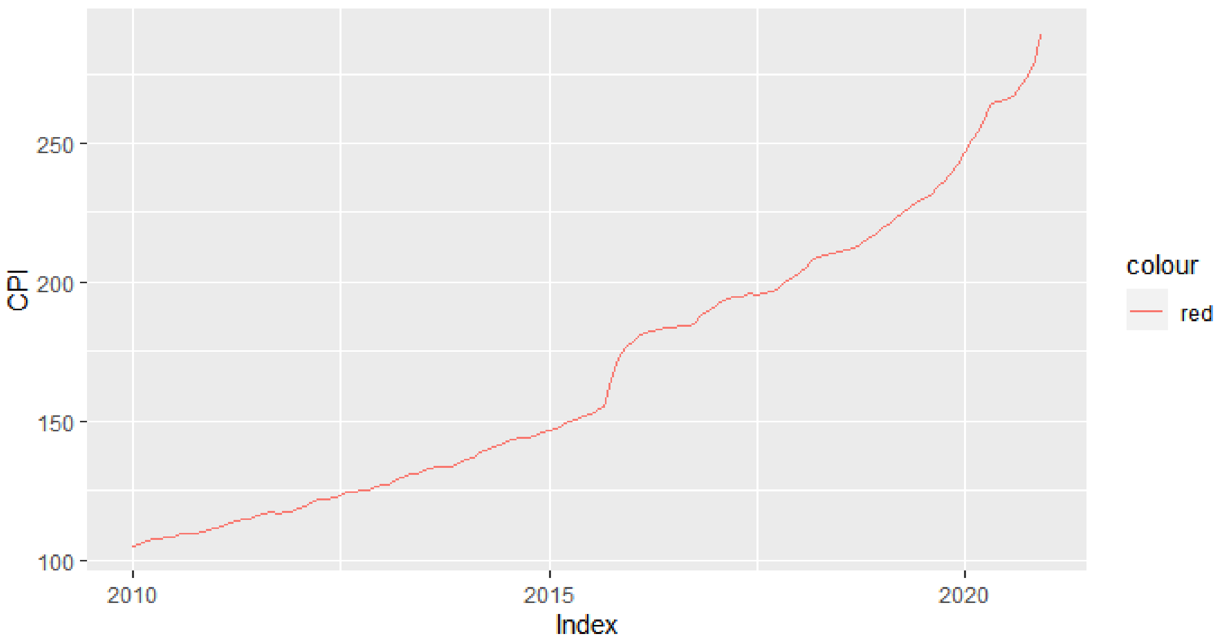

Figure 1. Time Series plot for the CPI of Zambia (January 2010-December 2020)

> CPI=zoo (df$CPI, as. Date(df$Date))

> autoplot.zoo (CPI, xlab="Date", ylab="Year", col="red")

The information above shows the analysis of the time series data set which contains the aggregated monthly Consumer price index (CPI) from 2010 January to December 2020 with 132 observations.

2.2 Testing the change in mean in the model

Christof 2021, says that Change in the mean is the most common and the simplest example and probably also the easiest to identify (at least visually). Alteration in the mean usually happens when a time series can be divided into different constant segments having different mean values. The mode of estimation of the standard regression model, the OLS (the Ordinary Least Square) method, is established on the assumption that the means and variances of these variables being tested are constant over time.

>library (change point) > fit_changepoint = cpt. mean (df$CPI.ts) > # Return estimates

> c (ints = param.est(fit_changepoint) $mean, + cp = cpts(fit_changepoint))

ints1	ints2	cp
127.7961	215.6882	70.0000

> plot(fit_changepoint)

The Change Point

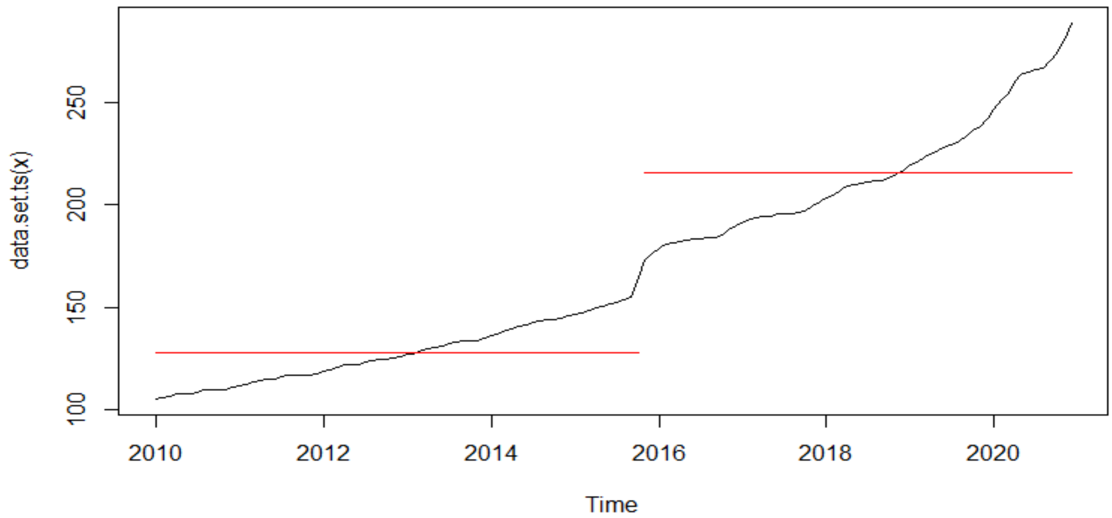

Figure 2. Shows that the model has structural breaks, the change point shows the change in mean in the time series.

2.3 Testing Stability using CUSUM test

CUSUM tests assess the stability of coefficients β in a multiple linear regression model of the form y = Xβ + ε. The cumulative sum of recursive residuals or the cumulative sum of OLS residuals to determine whether there is a structural break. Its Inference is based on a sequence of sums or sums of squares. Under the null hypothesis, the cumulative sum of residuals will have mean zero. The command also graphs the cumulative sum with confidence bands, which makes it possible for you to see whether the series behaves as the null hypothesis would predict.

> plot.ts(x) > plot.ts(df$CPI) > x1=ts (df$CPI, start=2010, end=2020, frequency = 12)

> plot.ts(x1) > y=efp (x1~1, type = "OLS-CUSUM") > plot(y)

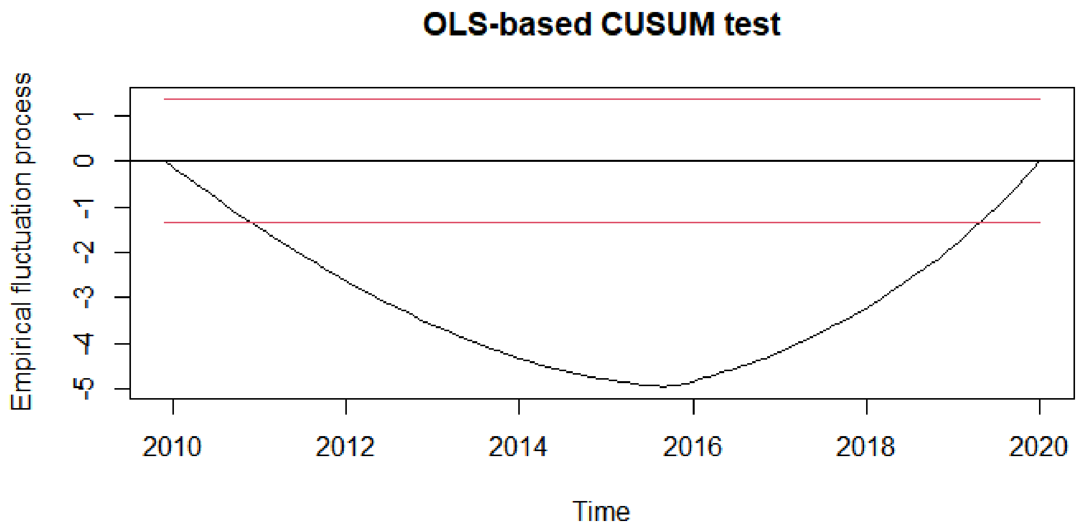

Figure 3. Empirical fluctuation processes (efp) Structural break in the Pattern of the series

Using formula that defines a linear regression model to be tested, the function efp forms an object of class "efp" which contains a fitted empirical fluctuation process of a specific type. When the black lines of the plotted graph are enclosed within the red lines, it means the hypothesis of structural break is rejected. However, since the plotted graph in the above fig3. Is out of the boundary lines there is a structural break in the pattern of the series.

2.4 Testing Stability for Chow test

To assess for structural breaks, we often use the Chow test. The model uses an F-test to determine whether a single regression is more efficient than two separate regressions involving splitting the data into two sub-samples.

Suppose we have a single regression line to fit the data points as $y_t = \alpha_0 + \alpha_1 x_t + u_t$, then where there is a structural break, we have two separate models expressed as:

$$y_t = \beta_1 + \beta_2 x_t + u_{1t}$$
$$y_t = \delta_1 + \delta_2 x_t + u_{2t}$$

Model 1 applies before the break at time t, model 2 applies after the structural break. If the parameters in the above models are the same $\beta_1 = \delta_1, \beta_2 = \delta_2$, then models 1 and 2 can be expressed as a single model as $y_t = \alpha_0 + \alpha_1 x_t + u_t$, where there is a single regression line. The Chow test examines whether the single regression line or the two separate regression lines fit the data best.

$$F = \frac{RSS_c - (RSS_1 + RSS_2)/k}{(RSS_1 + RSS_2)/(n-2k)}$$

1. Establish the critical values in the F-test tables, in our case it has F (k, n-2k) degrees of freedom.
2. Conclude, the null hypothesis by comparing with P-value.

2.5 Bai Perron Test

The diagram below shows the time series with multiple structural breaks and the breakpoints lines and confit lines within which break points can occur using Bai Perron test.

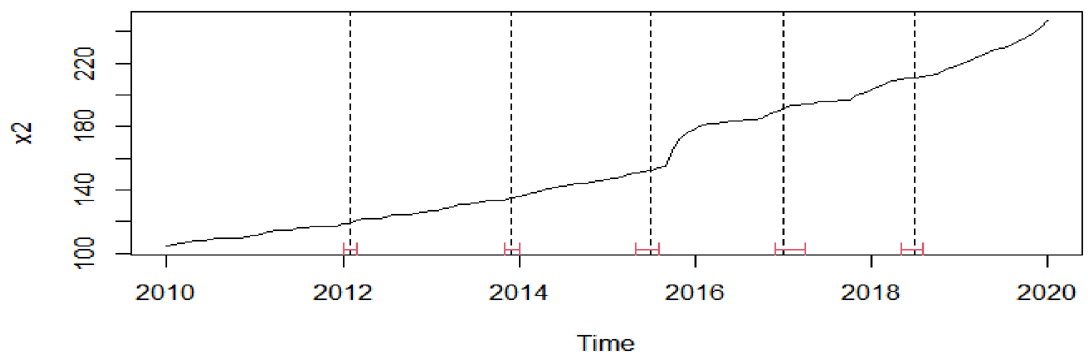

Fig 4. Structural break with breakpoint lines

3.0 RESULTS

Breakpoints at Observation number:

Sn	Observation number	Corresponding breakdates	Corresponding breakdates by %
1.	26	2012/02/01	0.1969697
2.	50	2014/02/01	0.3787879
3.	70	2015/10/01	0.530303
4.	94	2017/10/1	0.7121212
5.	113	2019/05/1	0.8560606

Summary table 3. Observations from the series pattern

> x2=ts (df$CPI, start=2010, end=2020, frequency = 12) > y1=breakpoints(x2~1)

>summary (y1)

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Optimal (m+1)-segment partition:

Call:

Breakpoints. Formula (formula = x2 ~ 1)

Breakpoints at observation number:

m = 1	70
m = 2	69 98
m = 3	39 70 98
m = 4	26 50 70 98
m = 5	26 48 67 85 103

Summary table 4

Corresponding to breakdates:

values	Breakdates
m = 1	2015(10)
m = 2	2015(9) 2018(2)
m = 3	2013(3) 2015(10) 2018(2)
m = 4	2012(2) 2014(2) 2015(10) 2018(2)
m = 5	2012(2) 2013(12) 2015(7) 2017(1) 2018(7)

Summary table 5. Breakdates of the structural break

Fit of the model:

m	0	1	2	3	4	5
RSS	207960.2	34345.6	19869.8	8978.4	6735.1	5908.3
BIC	1254.3	1046.0	989.4	902.9	877.7	871.4

Summary table 6.

Table 5 shows the summary of Bayesian information criterion (BIC) a criterion used for model selection and Residual Sum of Squares (RSS) a statistical technique used to measure the amount of variance in a data set that is not explained by the regression model.

In this case:

We reject the hypothesis that $\beta_1 = \delta_1, \beta_2 = \delta_2$

Using Bai Test and Chow's test to conclude that p-value is less than the Sup F test.

> sctest(model1)

Since sup. F = 462.03 greater than p-value < 2.2e-16, hence there is a structural break in the regression line.

3.1 DISCUSSIONS OF RESULTS

During the 7NDP period (2017 to 2021), inflationary pressures increased, and inflation averaged 12.0 percent. Single-digit inflation was attained during the SNDP and R-SNDP periods. Inflation was controlled within single-digit levels for most of the period, averaging 9.9 percent (%) between 2011 and 2015. Inflation increased to double-digit level in October 2015 (increasing to 14.3 percent (%) from 7.7 percent (%) in September (2015) largely on account of significant depreciation of the Kwacha (by over 72 percent (%) in the fourth quarter of 2015). The rate of inflation reverted to single-digit in November 2016 to 8.8 percent and was projected to remain within the single-digit margins for the rest of the year, (Republic of Zambia, 2017).

The stock of external debt increased substantially from 2012, following the issuance of Eurobonds in 2012, 2014 and 2015. Consequently, the external debt stock was US $6.94 billion at the end of 2016. The stock increased further to US $13.04 billion at the end of 2021. In addition, the Government had guaranteed external borrowing amounting to US$1.53 billion, mostly for power projects in the energy sector, (Republic of Zambia, 2022).

The rise in inflation was on account of increased food prices arising from the adverse impact of erratic rainfall on agricultural output and the pass-through from the depreciation of the Kwacha. These results agree with the Strong Fiscal Theory of the Price Level which argues that a fiscal dominant (non- Ricardian) regime exists when fiscal policy is not sustainable and government bonds are considered net wealth (Woodford, 1998). The wealth effects can jeopardize the objective of price stability, even when monetary policy is not accommodative to fiscal needs and is committed to the objective of low inflation. Within this regime, the only way to make the government's fiscal policy sustainable is through debt deflation, that is an increase in prices that erodes the real value of public debt and in turn the real value of financial wealth until a new equilibrium is reached. Fiscal policy can directly cause inflation through its effect on aggregate demand. The results also agree with the weak fiscal theory of the price level where a fiscal dominant regime exists and fiscal policy intervenes on the monetary policy rule.

The structural breaks suggest that Inflation is among economic indicators that track commodity prices (Chileshe et al. 2018). Zambia's high dependence on commodity exports makes it very vulnerable to commodity price shocks. Zambia as well imports most of its consumer, intermediate, and capital goods thereby making it vulnerable to foreign price shocks as well as exchange rate movements. Further, the improved integration into the global financial system has made Zambia exposed to external financial shocks. The financial reforms of the 1990s to adjust to a free-floating exchange rate in 1991 and complete liberalisation of capital and current account in 1994 imply that the increasing net private capital inflow makes Zambia vulnerable to reversals. The higher level of financial integration and a liberal capital account combined with flexible exchange rate makes

Zambia's macroeconomic performance and inflation in particular more vulnerable to external financial shocks.

4.0 Conclusion and Policy Implications

4.1 Conclusion

The study shows multiple structural break points in the pattern of the time series, change points in mean, and variance as well as in the pattern. From the several tests done, the series had 5 Structural changes or breaks in mean and variance and these were February 2012, February 2014, October 2015, October 2017, and May 2019.

The purpose of this paper was mainly to evaluate data of the Consumer Price Index (CPI) in Zambia in terms of structural breaks using R programming. Structural breaks or changes in the CPI of goods and services have to be studied as the consumer market is highly correlated with economic systems (Siti and Kasypi 2020). The country experienced a lot of structural changes in 2015, it was during this period that the country had the highest inflation rate of about 22.9. The changes in spending habits may be attributed to the structural breaks in relation to goods and services, consumption, and economic changes (Either growth or decline). Internal and external factors such as uncertainty in global economies, rebasing of the currency, implementation of new policies which may lead to a few conclusions drawn from the empirical tests above.

4.2 Recommendations

1. Policies should be put in place to diversify foreign exchange sources and increase earnings
2. Besides sound macroeconomic policies, strong debt management, and improved project appraisal is needed to maintain debt sustainability.

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