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Investigating temporal variation in the equity returns-inflation relationship in South Africa

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Abstract

The relationship between equity returns and inflation has been shown to be conflicting and inconsistent as well as time and country dependent. This is an issue in macroeconomics because equities are commonly regarded as a hedge against inflation. One potential explanation for the inconsistencies in the literature is the failure to account for structural breaks. This paper examines the possibility of structural breaks in both the consumer price index and stock market variables using the Zivot-Andrews (1992) and Gregory-Hansen (1996a, 1996b) procedures, which determined that the relationship exhibited evidence of structural breaks in both the individual series and in the relationship. The Fully-Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimation procedures were employed to investigate changes in the nature of the relationship, divided by the structural break. It was concluded that the relationship is subject to temporal variation and structural breaks should be considered, but that equities have acted as a consistent inflationary hedge in South Africa.

Keywords: *Inflation, equity returns, cointegration, structural breaks, South Africa Investigating temporal variation in the equity returns-inflation relationship in South Africa.*

1. Introduction

The Fisher Hypothesis (1930) predicts a positive relationship between expected real returns and real inflation and has suggested that equities, which act as a claim against real underlying capital assets, should act as an inflationary hedge as their returns should vary positively with actual inflation (Sharpe, 2002: 633). However, the one-to-one relationship between equity returns and inflation expected based on the theory of the Fisher Hypothesis has been shown to be inconsistent with much of the early literature, which typically exhibited evidence of a negative relationship (Fama, 1981; Gultekin, 1983: 50; Mayya, 1997: 61). Arnold and Auer (2015: 188) provide an extensive review of historical findings of the effectiveness of equities as an inflationary hedge and state that 'there is no consensus on whether these assets can hedge against inflation. This is because studies differ in their data sources, sample period and frequency, country coverage and/or econometric methodology.'

More modern studies that have utilised cointegration techniques, which test for a stationary linear combination of variables, have often shown a positive relationship (Alagidede and Panagiotidis, 2010; Kim and Ryoo, 2011; Arnold and Auer, 2015). The literature, however, also shows substantial disparity between studies that analyse different countries or consider varying time periods (Kim and Ryoo, 2011: 142). An underlying premise of the Johansen's (1996) cointegration test, however, is that the relationship is consistent over time. This, in reality, is not necessarily the case and variations in economic conditions can easily lead to a change in the dynamic of the cointegrating relationship in the long-run. As a result, a separate body of literature has developed in order to test for the possibility of a change in the relationship. While recent studies have typically found evidence of the existence of a positive relationship, they often also show temporal variance in the relationship (Ely and Robinson, 1997; Kasman, Kasman and Turgutlu, 2006). Antonakakis, Gupta and Tiwari (2017) show evidence that the relationship evolves over time in the United States, and provide significant evidence that while it may be positive in some periods, it is significantly negative in others. This largely contrasts the results of Kim and Ryoo (2011), who find that US stocks have provided an effective inflationary hedge, and thus a positive relationship, over the last century.

In addition to Antonakakis et al., (2017), studies that have considered potential changes in the relationship over time include those by Prabhakaran (1989) and Lee (2010: 1257) who determined evidence that the relationship is time varying. Furthermore, Boudoukh and Richardson (1993: 1354) discovered that the Fisher effect is stronger over longer time horizons, implying volatility in the relationship in the short-run. This highlights the fact that even if equity returns do act as an inflationary hedge in the long run, there is no reason to support the assumption that this relationship is necessarily consistent over time.

A combination of structural macroeconomic factors included in the sample set make South Africa a perfect natural experiment for investigating changes in the long-run dynamics of the equity returns-inflation relationship. These include the apartheid transition to democracy in 1994, before which the country was subject to international trade sanctions, the subsequent lifting of these sanctions, the reintroduction of South Africa to the global economy and the relaxation of exchange control mechanisms. The achievement of an investment grade sovereign risk rating and the positive effects on the economy, as well as substantial government-induced volatility in recent years also make it probable that the relationship has experienced a change. An occurrence that may have even more specifically affected the relationship is the introduction of the inflation targeting regime in 2000 (Mitchell-Innes, Aziakpono and Faure, 2007).

From an econometric perspective, such factors may have caused structural breaks in the data series. Esso (2010: 1384) states that previous studies such as that by Gregory and Hansen (1996a) have found evidence that conventional unit root tests, such as those used in the aforementioned studies which included South Africa, may fail to reject the unit root hypothesis in cases where a series that is in fact stationary contains a structural break. Cil Yavuz (2013) notes that the power of conventional unit root tests is reduced when a structural break exists and that they are biased to accept the null of a non-existent long relationship in such cases. This issue of potential structural breaks extends to the relationship itself, which, when considering the assumption typically adopted in the literature that the relationship has remained constant over time, even though there is no empirical basis for this assumption as demonstrated by Prabhakaran (1989) and Lee (2010: 1257); motivation to test for breakpoints in the magnitude of the relationship is provided. Testing for breakpoints in time-series has been previously considered and tests such as those by Gregory and Hansen (1996a,b) allow for an empirical analysis of relationships such as that between equity returns and inflation to determine if the relationship may have experienced breaks within the sample period.

Relatively few studies have examined the relationship between equity returns and inflation in South Africa and these studies do not show any real consensus in their findings. Alagidede and Panagiotidis (2010) discovered that both inflation and the stock price variable were non-stationary, and that they exhibit a significant positive relationship. Eita (2012), on the other hand, finds that both variables were stationary in level terms but still exhibit a positive relationship, albeit of a lesser magnitude than that discovered by Alagidede and Panagiotidis (2010). Khumalo (2013) discovered completely contrasting results, showing that while inflation is non-stationary in level terms, the stock price is stationary and that the magnitude of the relationship is negative and exceptionally strong, but the reasons for these findings remained largely unexplained. Moores-Pitt and Strydom (2017) employed a VECM methodology and found results similar to those of Alagidede and Panagiotidis (2010), but extended the analysis with the use of an ARDL model in order to relax concerns of the order of integration brought about by disparities in the aforementioned studies. This model finds that the relationship is still significant and positive over time, but of a lesser magnitude than suggested by the VECM.

In a multi-country study with six developed and six emerging economies, in which South Africa is included in the latter category, Moazzami (2010: 3) uses a dynamic model to allow for direct estimation of short and long-run impacts on stock prices caused by changes in the goods price. The data sample is larger than those of the other studies, running from 1970 to 2007 and uses an ADF test which rejects the presence of non-stationary residuals (Moazzami, 2010) while the coefficient of adjustment indicates that part of the disequilibrium between goods and stock prices is corrected in each period. The long-run adjustment coefficients do vary significantly between countries, but in the case of South Africa equals 1.0221, supporting the Fisher hypothesis that the coefficient is equal to unity. A potential explanation for these different findings may well be the aforementioned structural changes to the South African economy, or may simply be the use of different data formats as the sample data that is examined is not always clearly described. In fact, Mitchell-Innes et al. (2007) investigates the period following the introduction of inflation targeting between 2000 and 2005 and finds that during the short run, the Fisher hypothesis does not hold and cannot be confirmed in the long run while using a Johansen's (1992) cointegration test. This is in direct contrast to the results obtained when using the same test in the study by Alagidede and Panagiotidis (2010) and suggests that macroeconomic policy changes may well have influenced the nature of the relationship between equities and inflation. However, it is somewhat difficult to compare the two when considering the difference in sample lengths.

Finally, Phiri (2017) introduces a non-linear testing methodology and finds evidence that equities do not function as an effective inflationary hedge, although the author does find evidence that both series are integrated of the first order. This study is limited, however, in that the data set used is relatively short in comparison to alternative studies in the literature, starting in 2003 and ending in 2015, which excludes the introduction of inflation targeting as well as preceding data which may reflect changes caused by other macroeconomic events such as the transition from the apartheid regime.

A major potential issue with these South African studies, aside from their differing results, is that they do not consider that the relationship may not have been consistent over the periods they considered, but rather assume a constant relationship over time. Alagidede and Panagiotidis (2010) conduct stability tests over the sample period for South Africa, by way of an expanding window VECM that adds one observation consecutively and tests for cointegration with the goal of testing for changes over time and the identification of breaks. Alagidede and Panagiotidis (2010: 97) note that in most of the periods that are considered, oil price shocks, emerging market crises and institutional reforms play a role, which 'may induce structural shifts in the long-run relationship.' Furthermore, structural breaks in time series can induce apparent unit roots in the series when in fact they are stationary (Campos, Ericsson and Hendry, 1993). Indeed, Noriega and Ventosa-Santaularia (2006: 3) state that the complication in cointegration tests is the pre-testing problem which arises when identifying the order of integration of the variables. Alagidede and Panagiotidis (2010) find, using the expanding sub-period methodology that they employ, that cointegration has existed over the period for the South African case, but they do not test for changes in the magnitude of the relationship nor do they consider breaks while testing for stationarity before testing for cointegration.

Should breaks be shown to exist in the South African data, it is important to test if the cointegrating relationship has been affected. The possibility that the cointegration relationship experienced a change resulting from inflation targeting and structural changes in the market during the apartheid transition is theoretically plausible and would likely have important monetary policy implications.

In light of this, the research question is developed: has a structural break occurred in the relationship between inflation and equity returns in South Africa and, if so, has this break had a significant effect on the magnitude of the cointegrating relationship before and after the identified break date?

In section 2 the technical econometric framework is presented and the literature on the technical methods employed to investigate the research question is discussed. Section 3 briefly summarises the methodology and the data. The results are presented and discussed in section 4, while section 5 provides a conclusion to the study.

2. Technical econometric framework

2.1. Introduction

The primary problem addressed in this paper is the potential for structural breaks to exist in each series and in the cointegrating relationship in South Africa, which may have affected the capacity for equities to act as an inflationary hedge. We deal with time series data between 1980 and 2015 for both the equity returns and inflation variables. Time series data such as these are typically tested for a unit root prior to testing for a cointegrating relationship using tests such as the Augmented Dickey-Fuller test or the Phillips-Perron test in modern literature. Should these tests find evidence of a unit root, the conventional cointegration testing methodologies of Engle and Granger (1987) and Johansen (1988) are typically employed. Such testing is necessary to provide a baseline with which to build an analysis of the equity returns-inflation relationship in South Africa. These methodologies may however, incur errors by failing to account for structural breaks in the time series and in the relationship and because of the assumption of time-invariance, and as such newer methodologies are employed to account for this. This section discusses these newer methodologies.

2.2. Structural break testing

Previous studies in the literature have illustrated that it is possible for conventional unit root tests to fail to reject the unit root hypothesis in cases where the variable is in fact trend stationary with a structural break (Esso, 2010). Perron (1989) provides an example of the inherent bias of conventional unit root tests towards a false unit root null hypothesis when the data is trend stationary with a structural break. This was demonstrated using the Dickey and Fuller (1979) test when Perron (1989) developed a technique to test a series for a null hypothesis of a unit root with drift when an exogenous structural break occurs at time $1 < T_B < T$. The alternative hypothesis is that a unit root does not exist and that the series is stationary around a deterministic time trend with an exogenous change in the trend function at time T_B. Perron (1989) demonstrates that standard unit root tests are inconsistent when the alternative is a stationary noise component with a break in the slope of the deterministic trend, with the primary argument being that an exogenous shock with a permanent effect will not accept the unit root hypothesis even when it is correct.

Esso (2010: 1384) states that tests such as that by Perron (1989) have less power than conventional tests when there is no break. However, they are consistent irrespective of whether a break is or is not contained in the series and additionally provide results that are independent of the magnitude of the break. Gregory and Hansen (1996a) note that when there is a break in the intercept and or slope coefficient that the power of the conventional ADF test that does not allow for a regime shift falls substantially. In addition, Johansen, Mosconi and Neilsen (2000: 216) point out that during the economic time series analysis it is often required that the model accounts for breaks in the deterministic components. Johansen et al. (2000) mention Perron's (1989) methodology as one that allows for such breaks before they present a test which generalizes one of the three models by Perron (1989) for a case in which the break date is known. The primary controversy surrounding these tests is the assumption that the time of the break is known *a priori*, which can lead to the use of an incorrect break date and results in size distortions and power loss (Esso, 2010: 1384). Essentially, the methodology Perron's (1989) methodology allows one to test whether a series remains non-stationary even when it exhibits evidence of a structural break.

2.3. The Zivot-Andrews (1992) unit root test

Zivot and Andrews (1992) improve on Perron's (1989) methodology by extending the models to allow them to treat the time of the break as unknown. According to Zivot and Andrews (1992) the variation of Perron's (1989) test allows the breakpoint to be estimated rather than fixed which the authors deem to be more appropriate in order to avoid the problem of data mining. This test has an advantage over conventional unit root testing in that it allows one to test for the presence of a structural break within the series simultaneously. The Zivot-Andrews (1992) test examines the hypothesis of a unit root against the alternative hypothesis of a trend stationary process with a structural break (Zivot and Andrews, 1992: 254). Three regression equations capture this procedure.

Model A allows for a once-off change in the intercept, with a modified null hypothesis of a unit root which is represented as a dummy variable equal to one at the time of the break. Model B accounts for a change in the slope of the trend function without a sudden shift in the process at the time of the break (Perron, 1989: 1364). Model C accounts for a combination of changes in both the intercept and the slope of the trend function of the series, essentially capturing the functions of both Models A and B simultaneously (Zivot and Andrews, 1992: 253). In the case where the unit root captured in Model C is rejected we revert to testing Model A and B. The null hypothesis of Model A is a structural break with a unit root in the intercept. For Model B the null is a structural break with a unit root in the trend and for Model C the null is a structural break with a unit root in both the intercept and the trend. Drawing on the notation of Esso (2010) these models are presented as follows:

Model A (Intercept)

$$y_t = \mu + \theta DU_t(\tau_b) + \beta t + \alpha y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-1} + e_t$$

Model B (Trend)

$$y_t = \mu + \gamma DT_t(\tau_b) + \beta t + \alpha y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-1} + e_t$$

Model C (Intercept and Trend)

$$y_t = \mu + DU_t(\tau_b) + \beta t + \gamma DT_t(\tau_b) + \beta t + \alpha y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-1} + e_t$$

Where:

- $DU_t(\tau_b)$ =1 if t > τ_b and 0 otherwise, and $\gamma DT_t(\tau_b)$ = t-τ_b if t>τ_b and 0 otherwise.
- Δ is the first difference operator
- e_t is the white noise disturbance term
- DU_t is a sustained dummy variable that captures a shift in the intercept
- DT_t is a shift in the trend occurring at time τ_b
- The breakpoint τ_b is estimated using an OLS methodology for $T = 2,3, \ldots T - 1$
- τ_b is selected by the minimum t-statistic, $t_{\breve{\alpha}}$ on the coefficient of the autoregressive variables. $t_{\breve{\alpha}}$ represents the one-sided t-stat for testing $\alpha = 1$.
- *k* represents the number of lagged first-differences

Including too many extra regressors of lagged first differences does not influence the size of the test but decreases its power while including too few lags may significantly affect the size of the test (Perron, 1989: 1384). Zivot and Andrews (1992: 257) use an ADF approach to determine whether additional lags should be included and note that the number of extra regressors must increase with the sample size at a controlled rate. The same approach is followed in this paper, whereby the maximum lags included in the Zivot-Andrews (1992) test are dependent on optimal lag length endogenously determined during the ADF test. To clarify, prior to the use of the Zivot-Andrews test (1992) the ADF approach is employed in order to determine *k*, based on the Akaike Information Criterion (AIC). This approach in itself follows the approach initially presented by Perron (1989), who presents results of the Dickey-Fuller test for values of *k* ranging from 1 to 12.

2.4. Cointegration testing

The Gregory and Hansen (1996a) tests for cointegration are employed in this paper to investigate the relationship between equity returns and the inflation rate in the form of a two-step error-correction model. The Gregory and Hansen (1996a) tests are able to include a break in the cointegrating relationship, in contrast to the conventional tests of Engle and Granger (1987) and Johansen (1998).

Gregory and Hansen (1996a: 100) state that the model is concerned with a more general type of cointegration in which the cointegrating vector is allowed to exhibit a change at a solitary unknown time within the sample period. They state that they broaden the class of models being considered because their modified alternative hypothesis includes the Engle-Granger model as a distinctive subcase. This alternative hypothesis differs from conventional tests, while the null hypothesis of no cointegration is maintained. This model is spurred by the possibility of regime changes for situations in which several series are cointegrated but that the cointegrating vector has shifted during the sample period, at an unknown time. This differs from standard cointegration tests which assume that the cointegrating vector is time-invariant (Gregory and Hansen, 1996a: 100). For the sake of clarity, the aforementioned Zivot-Andrews (1992) test analyses the independent series for breaks, while the Gregory-Hansen (1996) test examines the relationship for cointegration in addition to a structural break in the relationship.

In line with the recommendations of Gregory and Hansen (1996), tests for parameter instability must be conducted prior to testing for cointegration. To test for this the Hansen (1992) test as well as the Recursive Residuals and Cumulative Sum of Squares (CUSUM) tests are used. The Recursive Residuals test shows a plot around a line at zero along with a positive and negative line at two standard errors from zero. If the residuals exceed the standard error lines the test suggests parameter instability in the equation. The CUSUM is based on the cumulative sum of the recursive residuals and plots the cumulative sum together with 5% critical value bands. Similar to the Recursive Residuals test the CUSUM test indicates parameter instability if the cumulative sum exceeds either or both of the critical lines.

For the Hansen (1992) instability test the L_c statistic is examined, initially including only a constant and then including a constant and trend variable. According to Esso (2010: 1388) the null of the L_c test is stability of the long run relationship which is tested against an alternative hypothesis of a change in the long-run equilibrium at some unknown point in the sample. The L_c statistic is particularly useful for testing for a gradual change in the cointegrating vector. The non-stationary estimation method used is the Fully-modified Ordinary Least Squares (FMOLS), discussed further in section 2.5, with default long-run variance parameters.

After finding evidence of parameter instability the Gregory-Hansen (1996a) test can be employed to test for cointegration with a structural break. Gregory and Hansen (1996a) propose tests that allow for cointegration with a regime shift in the intercept or the entire coefficient vector. They state further that the tests are essentially multivariate extensions of the univariate tests of Perron (1989) and Zivot and Andrews (1992), among others, which have been previously discussed. Gregory and Hansen (1992a) calculate critical values for up to four regressors using simulation methods, specifically evaluating the finite-sample performance of the tests using Monte Carlo methods based on the experimental design of Engle and Granger (1987). They discovered that the tests are able to determine cointegrating relationships between variables in the presence of a break in the intercept or slope coefficient, in situations where the power of the conventional ADF test, with no capacity to account for regime shifts, declines. Esso (2010:1385) presents the general long-run relationship used in the Gregory-Hansen (1996a) test that allows for a structural break in the regime and trend shift, shown below:

$$\ln(Y_t) = \mu_1 + \mu_2 D_t(T_b) + \beta_1 t + \beta_2 t D_t(T_b) + \alpha_1 \ln(E_t) \\ + \alpha_2 \ln(E_t) D_t(T_b) + \varepsilon_t$$

Where:

- The dummy variable $D_t(T_b) = 1$ if $t > T_b$ and 0 otherwise, where the unknown parameter T_b denotes the timing of the change point.

- Y_t = First Variable (Change to CPI)
- E_t = Second Variable (Change to SP)
- ε_t = white noise disturbance term
- μ_1 represents the intercept before the shift
- μ_2 represents the change in the intercept at the time of the shift
- β_1 = the trend slope before the shift
- β_2 = the change in the trend slope at the time of the shift
- α_1 = the cointegrating slope coefficient before the regime shift
- α_2 = the change in the cointegrating slope coefficient at the time of the regime shift

Esso (2010: 1385) states that the test for the null of no cointegration is residual based, where the above equation is estimated using OLS and a unit root test is applied to the regression errors following the methodology of Gregory and Hansen (1996a). The time break T_b is consistently considered to be unknown and is estimated with a data dependent method, with *T* representing the sample size (Zivot and Andrews, 1992). The date at which the structural break occurs will be when the unit root test statistics are at a minimum. The test, which is able to simultaneously account for a structural break and cointegration, will provide an indication of the possible effect structural breaks have had on the relationship over time, highlighting the effects of inflation targeting or other exogenous shocks on the equity returns-inflation relationship in South Africa.

2.5. Parameter estimation

The parameters in the long-run model are estimated using the FMOLS method of Phillips and Hansen (1990) and the Dynamic Ordinary Least Square (DOLS) estimator of Stock and Watson (1993), following studies by Eggoh, Bangake and Rault (2011), Gocen, Kalyoncu and Kaplan (2013); Cil Yavuz (2014) and Vogelsang and Wagner (2014). According to Vogelsang and Wagner (2014) the FMOLS approach makes use of a two-part transformation in order to remove the asymptotic bias terms, and allows for the direct estimation of cointegrating regressions. As a robustness check we employ the DOLS estimator alongside the FMOLS based on the work of Eggoh et al. (2011) who note that it is possible for the FMOLS to exhibit small sample bias and that the DOLS estimator appears to outperform the FMOLS in certain cases. The DOLS estimator uses parametric adjustment to the errors by including the past and future values of the $I(1)$ regressors with the intent to correct for endogeneity in the model (Eggoh et al., 2011). Following Cil Yavuz (2014) in the case of a structural break, two sub periods are defined before and after the date of the break for which the parameters are estimated using the aforementioned estimators. This allows one to observe changes in the relationship between the two periods, in order to determine whether or not the relationship has changed or remained consistent over time.

3. Methodology and data

The conflicting evidence in South Africa suggests that structural breaks may have occurred but no study to date has accounted for this possibility. As has been seen in the technical econometric framework the proposed methodology is designed to answer the research question of whether a structural break has occurred in the equity returns-inflation relationship, and if so, what its effect on the magnitude of the cointegrating relationship has been between the two periods. As discussed in section 2, there are established techniques to test for structural breaks in time series data.

Using the techniques discussed in section 2, a structural break testing methodology was utilised in order to conduct the cointegration analysis. Initially each series was tested individually for a single structural break, then tested for parameter instability in the relationship. The possibility of structural breaks in each variable is examined using the Zivot-Andrews (1992) test, which is able to determine whether either of the series independently contains a structural break and if whether or not the series was stationary before testing the relationship between them for a structural break with the Gregory-Hansen (1996) test. A necessary precondition for further cointegration testing is the finding of non-stationarity in the case of each variable. The Hansen's (1992) L_c test was used alongside a Recursive Residuals test and a CUSUM to determine parameter instability, after which the Gregory Hansen (1996a) test was used to test if the cointegration relationship holds while accounting for the most significant break in the relationship. In the case of cointegration The FMOLS and DOLS were then employed to estimate the cointegrating equation in order to assess whether or it provided evidence of a change in magnitude, or was proven to be time-invariant.

In terms of the sample, monthly data was obtained from the Johannesburg Stock Exchange (JSE) in the form of the All Share Index, which was converted in log form and used as a proxy for equity returns. This was made available upon request directly from the JSE. The monthly inflation data is publicly available from StatsSA in the form of the Consumer Price Index (CPI), which acts as a proxy for inflation. In the case of CPI, headline index numbers were used where December of 2012 was used as the base year and set equal to 100. Both series span the period between 1980 and 2015 and were converted into natural log form prior to use following Kim and Ryoo (2011). Using these data sets as proxy variables is well precedented in the international literature (Ely and Robinson, 1997; Alagidede and Panagiotidis, 2010; Kim and Ryoo, 2011) and it is assumed that the theory that current stock prices reflect future dividend payments holds (Moolman and du Toit, 2005: 88). The sample range covers the international trade sanctions, the apartheid transition period and subsequent reintroduction of South Africa into the global economy, the introduction of the inflation targeting regime and the period in which South Africa gained a positive sovereign investment grade rating, as well as changes to the computation method of the ALSI in 2002. This makes the sample suitable for the consideration of structural economic changes in South Africa's recent history.

4. Results

Section 4 presents the results of the methodologies discussed in section 3. Initially graphs of the logs of SP and CPI are shown in Figure 1.

4.1 Zivot-Andrews unit root test results

Table 1 shows the results of the Zivot-Andrews test for each variable using each model. The ADF test described earlier is used to determine the maximum lag length to be included for each series. The Zivot-Andrews test then selected optimal lag lengths for each test, these being 1 for LogSP and 12 for LogCPI. LogSP and LogCPI in the table show the Zivot-Andrews test statistic for each case.

It is evident that for the stock price variable, LogSP, the null cannot be rejected in Model C, showing that a unit root with a structural break exists in both the intercept and the trend. In the case of the inflation variable, LogCPI, the null hypothesis cannot be rejected at the 5% level as indicated by Model C which indicates that a unit root exists with a structural break in both the intercept and trend. Esso (2010: 1386) states that only in the case of significance of Model C where the null is rejected, we revert to the use of Model A or B and otherwise use Model C. In light of this, we do not need to consider the results of Model A or B in either case as the null of a unit root with a structural break in both the intercept and the trend cannot be rejected for either series. The results of Model C, the test with a break in the intercept and trend, are presented in Figures 2 and 3.

The largest break for LogSP occurred in 1998: 05, while the largest break for LogCPI occurred in 1990: 08. The break in LogSP is likely linked to decreased investor confidence and trade disruptions caused by the Asian financial crisis of 1997, which Corsetti, Pesenti and Roubini (1999) state may have itself been caused by sudden shifts in market expectations and confidence, especially with key trade partners such as China. The Asian Financial Crisis started with a currency market failure in Thailand after a government decision to no longer peg the Thai Baht to the US Dollar, resulting in currency declines that spread through South Asia leading to stock market declines and reductions in imports. Market declines were subsequently experienced in the United States, Europe and Russia. A report by the Industrial Development Corporation (IDC) (2013) marks the period around 1998 as a 'dramatic downturn for South Africa, as its economy was concurrently adjusting to its reintegration in the world economy, including substantial trade liberalisation and structural adjustments.' According to Ricci (2006:191) the inflation rate in South Africa remained high due to a weaker monetary policy stance during the 1980s until the early 1990s. The high inflation rate and volatility was also caused in part by the anti-apartheid sanctions and the disinvestment campaign which was first legislated in 1986 by the United States, leading to massive foreign capital movement out of South Africa and upward pressure on the inflation rate. As part of this disinvestment campaign the majority of US firms with South African holdings left between 1980 and 1991 (Posnikoff, 1997). It was only in the early 1990s that a stronger monetary policy framework was employed which brought about a marked reduction in inflation in comparison to major South African trading partner countries (Ricci, 2006:191). The structural break detected by the Zivot-Andrews test reflects the relative volatility experienced during the year when headline year-on-year rates dropped to 13.3% from 15.1% in January of 1990 and climbed back to 15.3% by November of the same year. Effective stability and reductions in the inflation rate only really occurred in 1992, where CPI dropped below 10% for the first time in more than ten years, after which it exhibited a relative amount of stability following the end of apartheid and the introduction of the inflation targeting regime in 2000.

4.2. Testing for parameter instability

The results of the Zivot-Andrews (1992) test indicate that each series contains at least one unit root and thus the relationship cannot be tested using a simple OLS framework in case of the possibility of a spurious regression (Gujarati and Porter, 2009). To test the long-run relationship while avoiding this possibility, one would generally employ a conventional cointegration test. However, as noted by Esso (2010: 1385), these tests for the null of cointegration may be subject to reduced testing power in the presence of structural breaks because the residuals from cointegrating regressions capture unaccounted breaks and may as a result exhibit nonstationary behaviour, which the Zivot-Andrews tests do find during the sample.

To avoid the problem of reduced testing power in conventional tests, Esso's (2010) approach is followed where one considers non-linear techniques, specifically the Gregory-Hansen (1996a) cointegration tests which account for a break in the cointegrating relationship. Preceding the Gregory-Hansen (1996) test, one employs parameter instability tests including the L_c statistic, the Recursive Residuals and the CUSUM tests discussed in section 2.5. Beginning with the L_c statistic in Table 2 the null of a stable long run relationship was tested against the alternative hypothesis of a change in the long-run equilibrium relationship at an unknown point in the sample.

The asymptotic critical values for the L_c statistic are presented by Hansen (1992: 524) according to degrees of freedom (m+1). The relationship was tested with and without a trend variable and in both cases the null hypothesis of a stable long run relationship can be rejected and the alternative hypothesis that there is a change at an unknown point in the sample can be accepted. Next the Recursive Residuals test was run, shown in Figure 4, which shows a clear breach of the +- 2 standard errors at multiple points in the sample, the most significant being between 2005 and 2009 during the period of the global financial crisis. These points of significance suggest parameter instability in the model.

The CUSUM test, shown in Figure 5, shows two breaches of the 5% significance bands, one in 1988 where it briefly crosses the line after which it returns to within the 5% band and the second in 2007, from which it does not return. Similar to the other tests this indicates parameter instability and motivates the implementation of the cointegration tests proposed by Gregory and Hansen (1996a, b).

4.3. Gregory-Hansen (1996) test

Following evidence of parameter instability found in the previous tests, the results of the Gregory-Hansen (1996a) test are presented for the case of a level shift, a level shift with trend and a regime shift, referred to in Table 3 as Model 1, Model 2 and Model 3 respectively. The test statistic presented is the ADF statistic according to the AIC. Presented alongside this are the number of lags included in the model and the estimated date of the break. Critical values for the tests are calculated in Gregory and Hansen (1996a). The null hypothesis in each case is no cointegration, tested against an alternative hypothesis of cointegration.

As seen in Table 3, one can reject the null hypothesis of no cointegration in each case and therefore, regardless of the model used, accept the alternative hypothesis of cointegration between stock prices and the consumer price index. The lag length selected by each model for unit root testing is uniform irrespective of the model, being 4 lags. The tests each show the important result within the context of this study that each model determines significant evidence of cointegration along with the presence of a structural break.

There are a number of reasons as to why the break may have occurred in mid-2005. A likely reason for the change in the relationship are the relatively low levels of inflation experienced between 2004 and 2005 with year-on-year rates that ranged from 0.2 to 4.4 over the two years (StatsSa, 2016). This is in comparison to a year on year rate of 11.6 early in 2003 and 13.7 in mid-2008. The year-on-year rates in May and June of 2005 were 2.8 and 3.4 respectively. These low inflation rates fit with the goals of the inflation targeting regime which was introduced in South Africa in 2000, aiming to curb inflation below 6%. The inflation targeting regime has typically been fairly successful since its implementation with the marked exception of the period between 2007 and 2009, the same period as the global financial crisis, often considered to be the worst financial crisis since the Great Depression (Goh, Li, Ng, Ow Yong, 2015).

From a stock market standpoint 2005 showed the highest index return by year from 2000 to 2015, falling directly between years of negative return in 2002 and 2008. According to the IDC (2013) the South African economy recorded its highest growth rates since the 1960's between 2004 and 2007. Over the 2004 to 2006 period South African interest rates were in one of two remarkably low phases, leading to credit growth and stimulating a housing market boom alongside the increased stock market investment. This massive growth, in conjunction with the low inflation rates over the period, points to a significant structural change in the relationship observed by the Gregory-Hansen (1996a) test in mid-2005. This break date coincides perfectly with adjustments of South Africa's sovereign credit ratings by Standard and Poor's and Fitch, who both adjusted their evaluation of South Africa's investment grade to BBB+ in 2005. This rating indicates that the rating agencies both deemed South Africa to be worthy of a 'lower medium grade' rating, up from BB+, 'non-investment grade speculative' following the apartheid transition in 1995. These ratings have a substantial impact on investor confidence and a rating upgrade directly increases the rate of foreign investment.

4.4. FMOLS and DOLS results

Based on the results of the Gregory-Hansen (1996a) test, that being of a long-run cointegrating relationship with a structural break between the variables, the FMOLS and DOLS can be used to estimate the economic model. The break date shown by the Gregory-Hansen (1996a) test is used to separate the two sub-periods and the results are presented in Table 4.

It is clear from Table 4 that there is a significant difference in the LogCPI coefficient between the two periods, which remains the case regardless of whether the FMOLS or DOLS results are considered. The coefficients in the first period show that for a 1% change in LogCPI, LogSP will change by 1.19% (FMOLS) and 1.22% (DOLS). In the latter period the coefficients show a 1.59% (FMOLS) or 1.67% (DOLS) change in the stock price. All the coefficients are shown to be significant. The results show a far higher coefficient in the post-2005 period, indicating changes that are about 0.45% higher per 1% change in CPI than in the pre-2005 period. From these results, it can be said that equities maintained their function as an inflationary hedge in the 1980 to 2005 period, but performed as a more effective inflationary hedge in the latter period. It can also be seen that the relationship has changed over time, with it being higher following the structural break detected by the Gregory-Hansen (1996) test in 2005.

These tests were then replicated using sample periods based on multiple structural breaks in order to account for the possibility that more than a single shift has occurred in the relationship during South Africa's recent history. When the pre-2005 sub-period was tested for a structural break using the Gregory-Hansen (1996) test, the most significant break in the sub-period was detected in September of 1994. In the post 2005 sub-period, the most significant break was found in June of 2008. While these periods obviously exhibit lesser power and size properties due to the shorter sample lengths, each was still significant for both tests. These results are reported in Table 5. While multiple structural break testing methodologies are available, such as the Bai-Perron (1998) test, the Gregory-Hansen (1996) test was favoured in this study in order to determine the single most significant structural break during each period.

4.5. Multiple structural break results

As can be seen in Table 5, the cointegrating relationship exhibited changes in magnitude depending on the structural period measured, but remained positive and above unity in each period. From this it can be concluded that the equity returns-inflation relationship has been subject to multiple structural changes over the period and that while structural breaks affect the magnitude of the relationship, equities have in each period acted as an effective hedge against inflation in South Africa.

5. Conclusion

The aim of this study was to investigate changes in the equity returns-inflation relationship over time and to determine if these changes have caused the cointegrating relationship to change, thus questioning the assumption of time invariance. The Zivot-Andrews (1992) test showed that structural breaks have occurred over the sample period in both the stock price and CPI variables, with the most significant changes being in 1998 and 1990 respectively. However, it was still found that the variables are both non-stationary in levels, an important finding in this context given the disparity in the South African literature. Furthermore, it has been seen that the cointegrating relationship has experienced its most significant structural break in mid-2005, but that the cointegrating relationship still exists, based on the finding of cointegration by the Gregory-Hansen (1996a) model. The long-run elasticities were then estimated using the FMOLS and DOLS techniques, which found that there has been a significant change in the relationship coefficient before and after the structural break in mid-2005. The tests were then replicated for multiple structural breaks and found that while the magnitude of the relationship has experienced significant variance, equities have in each period acted as an effective inflationary hedge regardless of structural breaks.

Given this finding, we can address the research problem and state that structural breaks are indeed evident in the relationship and may well be a cause for the different results in the literature, but have no cause to question that the long-term cointegrating relationship has remained significant and positive, a pertinent finding in the South African case. Furthermore, it can be seen that the assumption of temporal invariance in previous South African studies is not necessarily accurate. This may partially explain the variance in results between previous studies in South Africa. These findings show that one should account for structural breaks and temporal variance when analysing the equity returns-inflation relationship and it cannot be assumed that the relationship is consistent over time. Interestingly, it does not appear that the inflation-targeting regime or the anti-apartheid sanctions had particularly significant effects on the relationship, but rather that the equity returns-inflation relationship in South Africa is primarily subject to political factors and global economic performance that affect foreign investment.

While this study has shown that the relationship does not remain consistent over time by providing evidence of a changing cointegrating relationship around a structural break, an analysis including a multiple structural break testing methodology test may provide further insights into the nature of the relationship when the time invariance assumption is relaxed. Furthermore, this study could be extended by the implementation of recent developments in cointegration theory that allow for the consideration of asymmetric adjustment, another factor that has been overlooked in much of the existing literature.

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TABLE 1: Zivot-Andrews Unit Root Test Results

Variable	Lag Length	Break Date	Model A	Model B	Model C
LogSP	1	1998: 05	-4.552872	-4.064942	-4.633738*
5% crit. val.			-4.93	-4.42	-5.08
LogCPI	12	1990: 08	-2.469797	-4.354663	-4.186123*
5% crit. val.			-4.93	-4.42	-5.08

* indicates the optimal model use in each case, where the null cannot be rejected.

TABLE 2: Hansen Parameter Instability test

	LC statistic	Stochastic Trends (m)	Deterministic Trends (k)	Excluded Trends (p2)	Prob
No Trend Variable	3.90439*	1	0	0	<0.0.1
Trend Variable	0.83872*	1	1	0	0.017

* We can reject the null at the lowest critical value for the Lc statistic (0.470)

TABLE 3: Gregory-Hansen test results

	Model 1	Model 2	Model 3
ADF Stat	-5.62168*	-5.41800*	-5.66620*
Break Date	2005:06	2005:06	2005:06
Lags	4	4	4

*Denotes a rejection of the null hypothesis.

TABLE 4: Results of the FMOLS and DOLS tests around a single break point

		1980-01 to 2005-06		2005-06 to 2015-01	
		FMOLS	**DOLS**	**FMOLS**	**DOLS**
LogCPI	**Coefficient**	**1.19287**	**1.22398**	**1.59059**	**1.67211**
	T-Stat	34.89551	37.93687	3.60779	12.00455
	Std. Error	0.03418	0.03226	0.44088	0.13929
	Prob.	0.00000	0.00000	0.00005	0.00000
Constant	**Coefficient**	**4.34814**	**4.15762**	**3.19644**	**2.56375**
	T-Stat	39.23568	29.64636	1.62449	3.84595
	Std. Error	0.11082	0.14024	0.19644	3.84595
	Prob.	0.00000	0.00000	0.10710	0.00030

*critical values for these tests are 1.65, 1.96 and 2.6 at the 10%, 5% and 1% levels respectively.

TABLE 5: Results of the FMOLS and DOLS tests for multiple structural breaks

Period	**FMOLS CPI Coefficient**	**DOLS CPI Coefficient**
1980:01 – 1994:09	1.14698	1.16925
1994:09 – 2005:06	1.26308	1.19707
2005:06 - 2008:06	4.35171	3.83714
2008:06 – 2015:01	2.52297	2.58831

FIGURE 1: Log of the Stock Price and CPI between 1980 and 2015

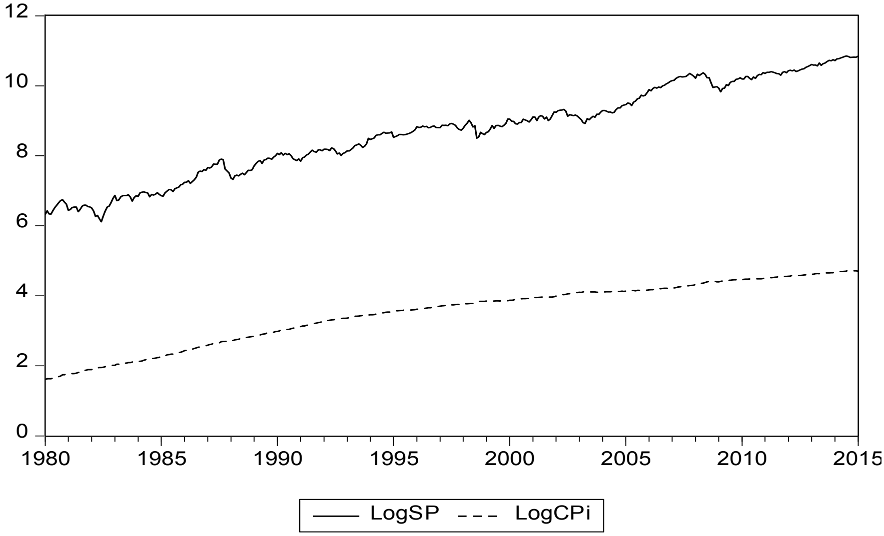

FIGURE 2: Graph showing the results of the Zivot-Andrews test on LogSP for Model C

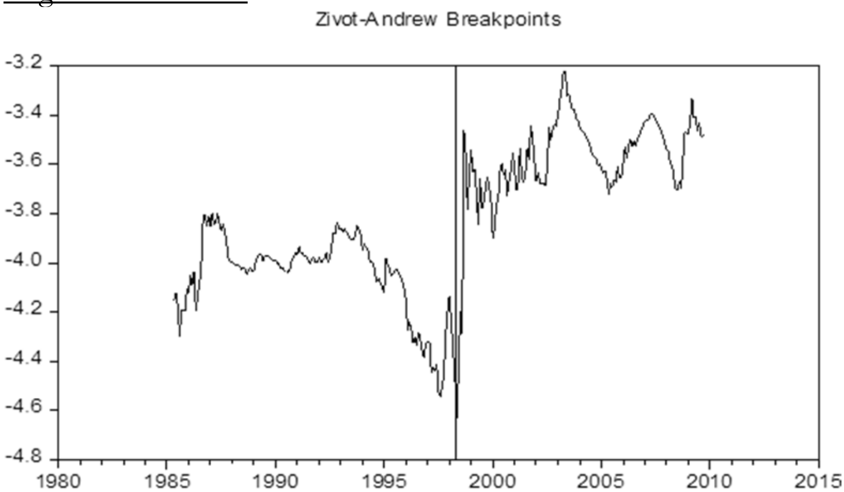

FIGURE 3: Graph of the results of the Zivot-Andrews test on LogCPI for Model C

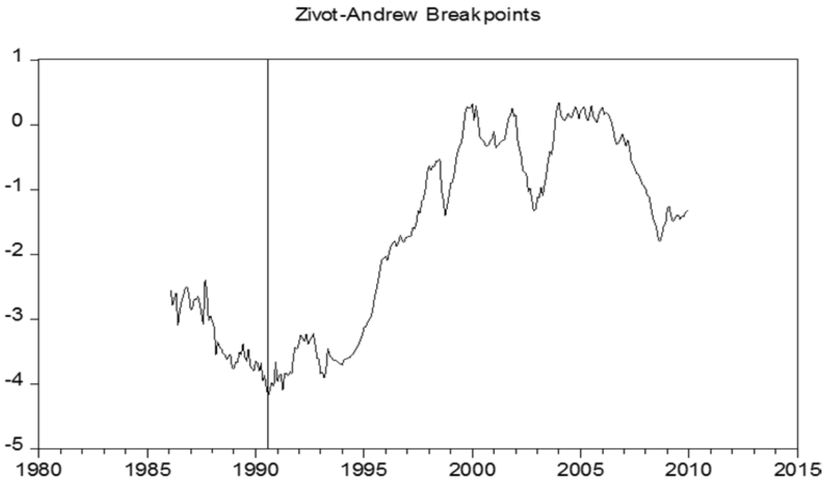

FIGURE 4: Recursive Residuals Test of the relationship between 1980 and 2015

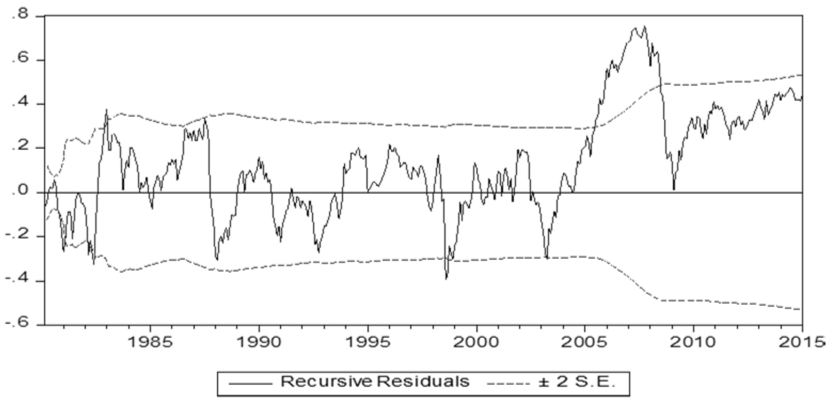

FIGURE 5: CUSUM test of the relationship between 1980 and 2015