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Trends and Structural Changes in South African Macroeconomic Volatility*

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Abstract

The international financial crisis that started in 2007 and the subsequent end of the long expansion in South Africa has refocused attention on the business cycle. Prior to the crisis, the economies of both developed and developing countries experienced an extended period of low and stable inflation and stable real economic growth, an episode that has been called the "great moderation". The disruption of this era by the financial crisis has highlighted the importance of understanding the nature and causes of the great moderation, to assist policy makers in facilitating its resumption. This paper considers the historical evidence for the great moderation in South Africa with the aid of a time-varying stochastic volatility model and various break-point tests.

Keywords: Business cycles, emerging market economies, quantitative analysis of business cycles

JEL classifications: C32, E32

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1 Introduction

Since the volatile 1970s, the economies of several developed and developing countries have become considerably more stable, with lower volatility for real output (and other macroeconomic series) coupled with low and stable inflation.[1] This development has been called the "great moderation" and was first observed in the economy of the United States, with comparable evidence soon emerging for other developed economies[2]. Du Plessis, Smit & Sturzenegger (2007*a*) and Burger (2008) have subsequently identified a similar moderation for the South African economy since the early to mid-nineties.

Though widely observed, and desirable from a welfare perspective, the nature and causes of the great moderation are not yet fully understood. Popular hypotheses ascribe the causes of the event to "good policy", an evolution of the economic structure, "good luck", or a combination of these factors.[3] Examples of "good policy" would include successful anti-cyclical monetary and fiscal policies by government, and/or better management of inventory investment by the private sector (Du Plessis et al. 2007*a*). Structural hypotheses focus on the importance of the relative expansion of the less volatile services sectors of the economy as an explanation for the great moderation. In contrast with the structural and "good policies" hypotheses, the "good luck" hypothesis suggests that the increasingly interlinked international economy (with more trade and capital flows) coincided with an exceptionally benign period of modest shocks that followed the spate of international disturbances of the seventies.

Burger (2008) recently considered three possible causes of the great moderation in South Africa (better monetary policy, a more efficient financial sector, and improved inventory management), all of which concern domestic factors and could be grouped under the "structure and good policy" headings. His evidence supported two of the three hypotheses, that is, better monetary policy and a more efficient financial sector contributed to greater economic stability, whilst better inventory management did not. His evidence on monetary policy extends earlier work by Du Plessis et al. (2007*a*), Du Plessis, Smit & Sturzenegger (2007*b*) and Du Plessis (2006) who provided evidence

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[1] A wealth of literature describes the nature and possible causes of this decline in volatility across many macroeconomic series since the volatile 1970s. The seminal papers with respect to the U.S. economy include: Kim & Nelson (1999), McConnel & Perez Quiros (2000), and Blanchard & Simon (2001).

[2] The early papers with evidence of the great moderation beyond the U.S. economy are Stock & Watson (2005) and Stock & Watson (2003*b*).

[3] See, for example, Gali & Gambetti (2009).

from a number of different analytical perspectives that monetary policy explains a large part of the great moderation in South Africa, with fiscal policy also contributing to this event.[4].

It has further been argued that the political situation in South Africa contributed to higher levels of economic volatility during the seventies, and Burger (2008) used the Soweto riots of 1976 and the political transition of 1994 as plausible boundaries for the period of macroeconomic instability in South Africa, while Du Plessis et al. (2007*a*) also used the 1994 transition as the demarcation line between the earlier period of instability and the more stable recent period.

In addition to local politics and policy, the stability of the South African economy is also affected by the international environment, especially since the economy is relatively small and open to both large capital flows and significant international trade. The international literature has attributed an important role in the great moderation to a more benign international environment,[5] which was transmitted to local economies via trade and capital market connections. This is an increasingly important factor in the South African context because it coincided with the liberalisation of the capital account and the promotion of greater trade liberalisation after the late eighties.[6].

The evidence on causes of the great moderation cannot, however, be separated from the question of dating the great moderation, as the identification of changes in policy, practice or international conditions need to match the observed changes in macroeconomic volatility to support these particular hypotheses. In contrast with the international literature, where much effort has been spent investigating this question, less attention has been directed towards this area of research in South Africa, with authors like Du Plessis et al. (2007*a*) using the political transition of 1994 as an implicit start, while Burger (2008) used "ocular inspection" to split the post-1960 history into three samples: 1960 to 1976 (a period of stability), 1976 to 1994 (a period of high volatility) and post-1994, a period of great moderation.

The contribution of this paper lies firstly in a more rigorous identification of the start of the

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[4]There has been some controversy in the South African literature over the extent to which fiscal policy has stabilised the economy. A number of authors have argued that fiscal policy has become pro-cyclical in recent years, including Burger & Jimmy (2006) and Frankel, Smit & Sturzenegger (2007) This has been attributed to ineffective automatic stabilisers by, for example, Swanepoel & Schoeman (2003) and Swanepoel (2004). More recently, this evidence has been disputed after the cyclical component of government revenue was estimated using more rigorous techniques and model-based assessments of the cyclicality of fiscal policy, by Du Plessis & Boshoff (2007) and Du Plessis et al. (2007*a*).

[5]See, Ahmed, Levin & Wilson (2004), Blanchard & Simon (2001), and Sensier & Dijk (2004).

[6]The extent of trade liberalisation is demonstrated in Edwards & Lawrence (2006) The history of capital account liberalisation can be found in Gidlow (2002).

great moderation in South Africa, and secondly, it motivates the use of time-varying stochastic volatility models to describe the nature of the declines in volatility. Such models have been used to good effect by Stock & Watson (2003*a*), who conduct an extensive investigation into the time-varying characteristics of volatility in the United States.

In the following sections, we describe the data before we present the formulation of the stochastic volatility model. This is followed by the results of the model and a number of break-point tests in both univariate and multivariate settings to derive a specific date for the observed changes.

2 The volatility of South African macroeconomic data

To provide an initial description of the South African business cycle, we make use of a Band-Pass and Hodrick-Prescott filter to identify the cyclical component of South African real GDP, reported in Figure 1.[7] We note that during the 1960s and early 1970s the cycle seems to be relatively volatile, although the amplitude of the cycle is not too dramatic. During the mid 1970s to the early 1980s, the cycle seems to be less volatile, but in this case, the amplitude of the cycle increases significantly. During the late 1980s to the most recent financial crisis, the cycle seems to have become stretched[8] (i.e. longer phases) with lower volatility. This observation is confirmed in Table 1, where we note that the year-on-year volatility of GDP first increased and then decreased over the five decades in the sample.

Such a decline in volatility has important implications for policy makers, given the welfare gains that may be derived from a less volatile business cycle, both directly (i.e. as a result of better decision making) and indirectly (i.e. through a lower risk rating). Policy lessons could also be derived from understanding the nature and cause of the changes in volatility. A further (technical) reason for investigating the time varying properties of the business cycle is that it may affect the formulation of appropriate econometric business cycle models.

In the following analysis, we investigate the properties of the expenditure and production components of GDP, as well as measures of employment, wages, inflation, production, interest rates, and exchange rates. This data is measured at a quarterly frequency after eliminating trends and obvious non-stationarity. In terms of the components of GDP and prices, these are all expressed

[7] All the tables are contained in Appendix A and all the figures are contained in Appendix B.

[8] See also, Du Plessis (2004).

as first-difference growth rates (i.e. $\log(y_1/y_2)$), and interest rates are expressed as annualised first differences (i.e. $y_1 - y_2$). Comprehensive details of the data sources and transformations are provided in Table 2.

To summarise the changes in the volatility of South African components that are likely to impact on the GDP growth rate, Table 3 reports the standard deviations of 32 economic time series for each decade over the period 1960q2 to 2011q4. Each decade's standard deviation is scaled by the standard deviation of the full sample for that series, with values less than one indicating a period of low volatility relative to the full sample period.

According to this measure, the volatility of the majority of the variables in Table 3 were highest during the eighties. These high levels of volatility subsequently subsided, though the disruption of the international financial crisis and associated local recession raised the volatility of a few series during the 2000s to levels above their full sample averages. The latter are consumption of semi- and non-durable goods, fixed capital formation of residential buildings, exports of goods and services, and manufacturing production. Although we do not report the results here, it is worth noting that until the recent financial crisis, none of the major components of GDP was more volatile in the 2000s than over the full period. To investigate the nature and timing of this decline in economic volatility, we use a time-varying stochastic volatility model that is described in the following section.

3 Modelling time-varying stochastic volatility

To model changes to the behaviour of time series that may be influenced by non-stationary characteristics, we make use of a state-space model that includes time-varying parameters.[9] In this framework, the evolution of an observed variable of interest is modelled by latent (or unobserved) state variables in what is called the measurement equation, while the evolution of the state variables is described by respective state (or transition) equations. When this framework includes state equations that are used to describe the volatility of a time series, it is often termed a stochastic volatility (SV) model. These models facilitate an intuitive representation of volatility, which is seldom constant, predictable, or directly observable.

[9] See, Durbin & Koopman (2001) for a textbook reference on these methods

Stochastic volatility models have been used extensively in mathematical finance to model the volatility of securities and these models have a similar structure to the widely used generalised autoregressive conditional heteroscedasticity (GARCH) models. These two types of models have been used to describe the same stylised facts, that relate to the volatility of a time series. However, where the GARCH model is formulated to model the total conditional variance of a variable, the SV model treats volatility as a latent stochastic process (where shocks to the volatility may be isolated from the underlying signal for this process).

The basic SV model describes deviations of an observed economic variable, y_t, from its mean, μ; as the product of its volatility, σ_t, and a stochastic error term, ϵ_t. Hence the measurement equation may be specified as,

$$y_t - \mu = \sigma_t \epsilon_t \qquad \text{where } \epsilon_t \sim \text{i.i.d.} N \left[0, \varsigma^2_{\epsilon_t} \right]. \tag{1}$$

The distribution of volatility may then vary over time by including an unpredictable component, υ_t, in the specification of the σ_t process. Hence, the specification of the state equation that may be used to describe the volatility of the observed variable, σ_t, may be expressed as,

$$\log \sigma^2_t = \log \sigma^2_{t-1} + \upsilon_t \qquad \text{where } \upsilon_t \sim \text{i.i.d.} N \left[0, \varsigma^2_{\upsilon_t} \right], \tag{2}$$

where the use of logarithms ensures non-negative conditional variances.[10, 11]

To allow for various degrees of persistence and parameter-drift in the mean of the respective time series, we followed Stock & Watson (2003*a*) and assume that the data follow AR(4) processes that are subject to time-varying mean behaviour.[12] The inclusion of parameter drift in this instance is supported by our earlier findings, and several authors including Cogley & Sargent (2001), suggest that by allowing for such behaviour we are at least consistent with certain elements of the Lucas (1976) critique.

[10]For the interested reader, Shephard (1996) provides an introductory survey of SV and ARCH models. Ghysels, Harvey & Renault (1996) provides a mathematical review, and Shephard (2005) provides a more recent review of important SV papers.

[11]Note that in this specification, we are seeking to obtain parameter values for the variance of two shocks (i.e. one for σ_t and one for ϵ_t) using information from a single observed variable, y_t. This may result in several difficulties with parameter estimation in such a model.

[12]The use of different autoregressive structures, including AR(2), AR(3), AR(6) and AR(8) processes did not influence our findings significantly. If anything, the use of additional autoregressive lags identified more potential break-points. However, the pronounced decline during the 1980s was material and consistent, across all lag lengths.

Therefore, we extend the above measurement equation in the model and assume that the stochastic factors are independent and identically distributed with zero mean and unit variance, such that,

$$y_t = \sum_{j=1}^{4} \alpha_{j,t} y_{t-j} + \sigma_t \epsilon_t; \qquad \text{where } \epsilon_t = \text{i.i.d.} N\left[0,1\right] \tag{3}$$

with the state vector that describes the time-varying persistence of the data,

$$\alpha_{j,t} = \alpha_{j,t-1} + \theta_j \varphi_{j,t}; \qquad \text{where } \varphi_t = \text{i.i.d.} N\left[0,1\right]. \tag{4}$$

This formulation suggests that following the arrival of new information, changes to the economy take place that affect α_t, which is modelled as a random walk process. The value for θ_j is then calibrated at $\theta_j = 7/T$, which is consistent with the estimate of Stock & Watson (2003*a*) for parameter drift in autoregressions.[13]

The time-varying volatility of the variable may then be described by the second state equation,

$$\log \sigma_t^2 = \log \sigma_{t-1}^2 + \upsilon_t^2. \tag{5}$$

To allow for large jumps or breaks in the variance (σ_t^2) we use a mixture of distributions for υ_t, which include a period of low volatility, $\upsilon_t = N(0, \tau_1^2)$ with probability q, and a period of high volatility, $\upsilon_t = N(0, \tau_2^2)$ with probability $1 - q$. In this instance, we set $\tau_1 = 0.04$ and $\tau_2 = 0.2$, as per the estimates of Stock & Watson (2003*a*).[14] The probability of the variable being in a state of low volatility at a particular point in time is calibrated at 0.95.[15]

A non-Gaussian smoothing algorithm was then used to identify the trend in the unobserved volatility of the respective time series. This was necessary as the conventional linear Gaussian model framework with a small amount of noise for the variance often fails to detect large jumps in

[13]We considered the implications of using different measures of θ_j and found that the respective variables are extremely insensitive to the degree to which the persistence is allowed to vary. When we decrease the value of θ_j the results do not change materially, whilst much larger values of θ_j increase the significance of our findings.

[14]Our results are not sensitive to the specific choice of these values. Varying the value of τ_1 hardly affects the results reported in the text; while a lower value of τ_2 results in slightly smoother time-varying volatility and a larger value leads to a slight increase in the volatility of each of the respective time series.

[15]The results that we report are not largely dependent on the calibrated value of q. Decreasing the probability of an event arising during a period of low volatility increases the reported time-varying volatility, whilst increasing the value of q produces a flatter overall trend for the time varying volatility.

volatility (which may be due to shocks) or gradual (smooth) changes to the trend. In addition, the exclusion of a large amount of noise in the variance of the stochastic factor, υ_t, would introduce several inappropriate high-frequency elements to the trend of a linear Gaussian model.[16]

The parameters in the model are estimated using Bayesian techniques, where initial conditions are established with flat priors. Thereafter, diffuse conjugate priors were used to obtain parameter estimates. In such a setup, we are able to make use of the extremely powerful Markov Chain Monte Carlo (MCMC) methods for the non-Gaussian smoother, as suggested by Stock & Watson (2003*a*).

Where $Y = y_1, ..., y_T$, $A = \alpha_{j,t}; j = 1, ..., 4; t = 1, ..., T$ and $S = \sigma_1, ..., \sigma_T$, the MCMC algorithm is formulated to iterate between the following three conditional distributions of $[Y|A, S]$, $[A|Y, S]$, and $[S|A, Y]$. The first two conditional distributions are normal and the third is computed by approximating the distribution of $\log \epsilon_t^2$ with a mixture of normal distributions that have means and variances that match the first four moments of the $\log \chi_1^2$ distribution, in the multimove Bayesian sampler of Shephard (1994).

After the parameter values have been estimated with the use of non-Gaussian smoothing algorithm, the estimated instantaneous autocovariances of y_t are then computed using $\sigma_{t|T}^2$ and $\alpha_{j,t|T}$, which converge on the conditional means of σ_t^2 and $\alpha_{j,t}$, given the observed time series. The smoothed instantaneous variance in the growth rates are then calculated by summing up the instantaneous autocovariance functions in chronological order.

3.1 Results of time-varying stochastic volatility model

The resulting time-varying stochastic volatility of South African GDP is depicted in Figure 2, where the green line depicts the mean absolute deviation[17] and the blue line is the smoothed estimate of the instantaneous time-varying standard deviation of the stochastic volatility model.

This graph shows that the decline in real output volatility in South Africa may have started as early as the middle of the 1980s, as the volatility of the series declines sharply between 1983 and 1987. Figure 2 also shows steadily declining volatility from 1992 onwards. When considering the graphs for the constituent parts of South African GDP expenditure that are included in Figure 3,

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[16] See, Kitagawa (1987).

[17] The absolute difference between each y_t and the full sample mean.

we note that the large decline in volatility during the 1980s is relatively widespread. For example, consumption, government expenditure, and investment (over output) all seem to experience a similar decline. Gross fixed capital formation and imports also experience such a decline, but it would appear to take place with an additional lag (i.e. only starting in 1987), whilst exports maintain a relatively constant level of volatility over this period. In addition, we also detect similar findings with regard to the value-added side of the economy (with the exception of the primary sector).

With regard to employment measures, we observe little change to the volatility of the respective series, whilst the volatility of the consumer price index was higher in the eighties, declined during the nineties and has lately been on an upward trend again. The higher volatility of interest rates since the mid-nineties is clearly depicted in the remaining few graphs.

The following tentative conclusions are possible at this stage: *firstly*, real output and its major constituent parts experienced significant shifts in their mean growth rates and volatility, rejecting any notion of co-variance stationarity. *Secondly*, a sizeable downward shift in the conditional variance of real output seems to have started in the early to mid-eighties; a date which is much earlier than previously estimated in the South African literature, but in line with the estimated start of the international 'great moderation' (especially for the United States).

4 Break-point investigation

It is possible to identify the likely start of the great moderation in South Africa more rigorously by applying break-point tests to the conditional volatility series. We first apply a simple turning-point test that was popularised by Wecker (1979), whereby potential downturns start at local peaks in the series under investigation $(y_{t-4}, y_{t-3}, y_{t-2}, y_{t-1} < y_t > y_{t+1}, y_{t+2}, y_{t+3}, y_{t+4})$ and upturns start at local troughs, that is, $(y_{t-4}, y_{t-3}, y_{t-2}, y_{t-1} > y_t < y_{t+1}, y_{t+2}, y_{t+3}, y_{t+4})$.

These turning-points provides us with a set of possible break-points in the volatility of the respective variables, and they have been included in Figures 2 through 5. To ascertain whether these turning points are statistically significant, we subject the series to a number of break-point tests that also determine whether the change in volatility is associated with changes in it's time-varying mean (or trend), or with its associated conditional variance (or volatility). Distinguishing between these types of breaks is important, since changes to the trend may be associated with changes in economic policy or other events that evolve over time, whilst changes to the conditional variance would be associated with the frequency and amplitude of economic shocks that are generally of shorter duration.

Essentially, these tests seek to identify changes in the parameters of the following autoregressive model.

$$y_t = \phi_t + \beta_t(L)y_{t-1} + \varepsilon_t \tag{6}$$

where,

$$\phi_t + \beta_t(L) = \left\{ \begin{array}{c} \phi_1 + \beta_1(L), t \leq \xi \\ \phi_2 + \beta_2(L), t > \xi \end{array} \right\} \tag{7}$$

and,

$$\varepsilon_t^2 = \left\{ \begin{array}{c} \varepsilon_1^2, t \leq \zeta \\ \varepsilon_2^2, t > \zeta \end{array} \right\} \tag{8}$$

These tests make use of the heteroscedasticity-robust Quandt likelihood ratio (QLR) statistic[18] that was implemented with the method of Bai (1997) to test for changes in the autoregressive parameters. In this specification the date of the break-point in the conditional time-varying mean is represented by ξ, which may differ from the date of the break-point in the condition variance that is given by ζ.

The results for GDP are reported in Tables 4 and 5. The first column provides the least squares estimate of the break date, the second column provides the 67% confidence interval around this date, and the final column provides an estimate of the significance of the break using the technique of Hansen (1997). The results for breaks in the trend refer to the ϕ and β parameters in equation (6), whilst the results for the conditional variance correspond to the ε_t in the same equation.

The results in Table 4 suggest that there are several instances where the mean growth rate has been subject to significant structural changes, whilst Table 5 indicates that there is only one instance where we observe significant changes in the conditional variance of the series. When we

[18]See, Quandt (1960).

consider these results in conjunction with those of the SV model, we note that most of the breakpoints coincide with the turning points in the earlier investigation. In addition, it is particularly interesting to note that the dramatic decline in output volatility that started after the fourth quarter of 1981 may be largely attributed to changes in the time-varying mean growth rate.[19] This significant decline in economic volatility came to an end at the start of 1986, after which the conditional volatility remained at a more consistent (or constant) level.

During the early 1980s, the monetary authorities in South Africa moved decisively away from direct controls and towards a market-oriented framework in domestic monetary policy and capital controls, following the publication of the interim report of the De Kock Commission[20] in 1978. The implementation of the commission's recommendations established a single exchange rate for the South African economy, which was allowed to float against other currencies.[21] The improved access to international capital markets and removal of direct controls domestically were meant to provide the capital market instruments that would smooth economic activity from the early 1980s onwards.

However, the South African economy's exposure to foreign debt had increased dramatically by the mid 1980s (from 20.3% of GDP in 1980 to 50.1% of GDP in 1985) and, what is more, was of a short-term nature.[22] Servicing this debt became particularly onerous as the rand depreciated on foreign exchange markets. In addition, this change to the structure of the capital account also raised the vulnerability of the economy to the adverse economic shocks that were imposed by the trade and financial sanctions, following the perceived abandonment of political reform in President P.W. Botha's "Rubicon" speech in August 1985. The rapid decline in output volatility that had been observed up to this point was arrested by the ensuing economic disruption.

These findings are largely supported by the CUSUM test statistics that are reported in Figure 6 and 7. The first of these graphs relates to the cumulative sum of the one-step ahead forecasting

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[19]There is some evidence to suggest that there could be a joint break in both the mean and the conditional variance. This is the only instance where there may be a joint break in the conditional mean and variance of GDP growth (when measured in each of the subsamples at the 5% level of significance). However, since there is no corresponding separate break in the conditional variance at this point in time, we presume that the break is largely attributed to developments in slower changing components of real output, that is, structural factors.

[20]Important impetus for this development derived from the De Kock Commission. See, De Kock Commission (1978) and De Kock Commission (1984).

[21]The unification of exchange rates took place in February 1983 to establish a single managed floating exchange rate mechanism.

[22]See, Khan (1987) and Farrel & Todani (2004).

errors for the residuals from the AR(4) model for output growth. It suggests that in the early 1980s, the forecasting errors increased somewhat to a level where they exceed the confidence levels, before continuing in a steady downward direction throughout the rest of the 1980s and early 1990s. Similarly in the second of these graphs, which relates to forecasting errors of the residuals from an AR(1) model for the volatility of output, we see that the forecasting errors exceed the confidence level around 1986 (at a point in time where they experienced a rapid change in direction).[23]

Such break-points, around the early to mid-1980s, have also been found in similar analyses that have been conducted for developed world economies; however, in many of these studies, including Sensier & Dijk (2004), Ahmed et al. (2004), and Stock & Watson (2005), the break-points were largely attributed to changes in the conditional variance attributable to benign shocks, rather than structural developments. By contrast, owing to the prominence of the break-point in the mean of real GDP, the South African evidence suggests a greater role for structural factors in the early phases of the great moderation.

Using the breakpoints of 1981q4 and 1986q1 we then consider which of the components of GDP had the largest influence over the observed decline in output volatility.[24] After weighting the components according to their contribution to output, it is not surprising to observe that the decline in the volatility of consumption had the most pronounced impact on the changes in output volatility over this period. Other important contributors include changes in the volatility of government expenditure, investment expenditure, production of durables, and imports. The perspective from a value added perspective is similar with services and tertiary activities making the largest contributions to the overall reduction in volatility. In addition, other measures of economic activity, such as consumer inflation and price deflators, also report large declines in aggregate volatility during the early 1980s.

Further test results for the most prominent break-points in the other economic series have been included in Table 7.

[23]The measure of volatility is derived from the above stochastic volatility model with the time-varying parameters. Since the model makes use of single lagged regressor in the volatility equation and four lags in the measurement equation we use an AR(4) for the mean and an AR(1) for the volatility.

[24]Table 6 contains these results.

5 Multivariate estimation of break-points

The great moderation refers to a period of benign stability in many macroeconomic aggregates and across most sectors of the economy. To complement the results for real output reported in the previous section, this section investigates possible break-points from a multivariate setting to identify common break points across various time series.

Following Bai, Lumsdaine & Stock (1998) we specify a low dimensional VAR model that makes use of multiple equations to obtain accurate confidence intervals for break-points in multivariate time series with either stationary or nonstationary characteristics.[25] This method can be regarded as an extension of the univariate regression that is described in equation (6).

Under consideration is a null hypothesis of no break-point against the alternative hypothesis of a common break in the system of equations. We tested three systems of equations with this approach: *first*, a decomposition of real GDP into its expenditure components, and *second*, a decomposition of real GDP into its value added components. The test statistic is the QLR statistic that is computed using the absolute values of the VAR residuals. The OLS estimates[26] of the break date in the mean absolute residual and the associated confidence intervals are also reported in Table 8.

The results of these multivariate tests are somewhat ambiguous. Whilst the joint consideration of the expenditure components of GDP (line 1) suggests an early break-point in support of the univariate results reported above, the decomposition into the value added components suggest a significant decline in volatility in the late 1960s and early 1970s. This result for the value added components is largely attributed to the tertiary sector, which experienced a rapid decline in volatility over this period. However, after removing the tertiary sector data from the value added components, the most prominent suggested break in the bivariate VAR arises in 1996, with a confidence interval that would include the period of political transition in 1994.

In the *third* model, we consider a decomposition of household consumption expenditure, since it has substantially influenced the decline in GDP volatility between 1981q4 and 1986q1. This model produces similar results to the VAR for the expenditure components and suggests that the most prominent change in 1987q1. The *final* model, combines the domestic variables that were

[25]This statistic would only be valid for large samples.

[26]To avoid overfitting the model we keep the VAR coefficients constant.

used in a recent macroeconomic forecasting model for South Africa.[27] These results are similar to those of the first and third model, with a suggested break taking place in 1988.

This ambiguity in the results is understandable, given the significant role of the changes to capital controls and political institutions in the evolution of aggregate volatility in the South African economy. Furthermore, it is also not surprising to note that a certain amount of ambiguity surrounds the question of the most important multivariate break-point, given the number of significant break-points that have been observed in the above univariate analyses for both the mean and the variance of the respective time series. In this sample period, for example, there are four distinct break-points in the mean of GDP and one distinct breaks in the conditional variance of GDP that are all significant at a 5% level of significance.

6 Conclusion

This paper investigates changes to the volatility of South African output and other macroeconomic time series over the period 1960q1 to 2011q4. The results suggest that the most significant change occurred during the 1980s, when output volatility declined by a significant amount between 1982 and 1986. This finding is consistent with the international literature that dates the "great moderation" during a similar period. However, in contrast with the international literature, longer run factors seem to have played a more important role in the moderation locally.

The gradual decline of volatility is consistent with a description of the South African economy undergoing a slow structural shift, with the evolution of macroeconomic policy away from direct controls and towards market-based interventions and with improved private sector management of inventories. The dramatic increase in the smoothing of consumption,government expenditure, investment expenditure, production and imports during the early 1980s would also suggest that economic agents were able to make better inter-temporal decisions over this period of time, which would have been possible following the liberalisation of, *inter alia*, the capital account.

The role of a decline in the conditional volatility of real output suggests that in South Africa, as elsewhere, a more benign environment (fewer and less disruptive shocks) also played an important role. Since this result emerges for many countries over the same period, it has been plausibly

[27] See, Alpanda, Kotzé & Woglom (2011) for a discussion of the variables in their DSGE and BVAR models.

connected with a period of benign international development, following the global shocks of the seventies. That the progress towards a more stable conditional variance was halted at the time of the most intense trade and capital sanctions provides further support for the suggestion that the international environment was an important factor in the South African great moderation.

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Appendices

A Tables

Table 1: Year-on-year growth rates for South African gross domestic product

Period	Mean	Std Dev
1960:1 1969:4	5.6	1.8
1970:1 1979:4	3.2	2.2
1980:1 1989:4	2.2	3.2
1990:1 1999:4	1.4	2.3
2000:1 2009:4	3.6	2.1
2000:1 2011:4	3.5	1.9
1960:1 2011:4	3.1	2.7

Table 2: Transformation of variables

Description	**Code**	**SARB code**	**Trans.**
Gross domestic product at market prices	gdp	KBP6006D	1
Final consumption expenditure by households: Total	cons	KBP6007D	1
Final consumption expenditure by households: Durable goods	cdur	KBP6050D	1
Final consumption expenditure by households: Semi-durable goods	csdu	KBP6055D	1
Final consumption expenditure by households: Non-durable goods	cndu	KBP6061D	1
Final consumption expenditure by households: Services	cser	KBP6068D	1
Final consumption expenditure by general government	gov	KBP6008D	1
Gross fixed capital formation	gfcf	KBP6009D	1
Gross fixed capital formation: Residential buildings - Total	gfcr	KBP6110D	1
Gross fixed capital formation: Non-residential buildings - Total	gfcn	KBP6114D	1
Change in inventories	$\text{inv} = \frac{\text{inv}}{\text{gdp}}$	KBP6010D	2
Gross domestic expenditure	gde	KBP6012D	1
Exports of goods & services	exp	KBP6013D	1
Imports of goods & services	imp	KBP6014D	1
Gross value added at basic prices of primary sector	gvap	KBP6630D	1
Gross value added at basic prices of secondary sector	gvas	KBP6633D	1
Gross value added at basic prices of tertiary sector	gvat	KBP6637D	1
Gross value added at basic prices of all industries	gva	KBP6645D	1
Total employment in the non-agricultural sectors	emp	KBP7009Q	2
Total remuneration per worker in the non-agric. sector	wage	KBP7013L	1
Total consumer prices (Metropolitan areas)	cpi	P0141.1*	1
Gross domestic product at current prices	$\text{def} = \frac{\text{gdp}_{\text{nomimal}}}{\text{gdp}_{\text{real}}}$	KBP6006L	1
Manufacturing : Volume of production of non-durable goods	prn	KBP7084N	1
Manufacturing : Volume of production of durable goods	prdu	KBP7083N	1
Manufacturing : Total volume of production	prod	KBP7085N	1
Manufacturing: Labour productivity	lpr	KBP7079L	1
Manufacturing: Unit labour costs	lct	KBP7080L	1
Notice deposits with clearing banks : 32 days	noti	KBP1414M	2
Discount rates on 91-day Treasury Bills	tbil	KBP1405W	2
Yield on loan stock traded on the bond exchange: Government stock	govs	KBP2003M	2
Yield on loan stock traded on the bond exchange: Eskom stock	esk	KBP2004M	2
Foreign exchange rate : SA cent per USA dollar (R1 = 100 cents)	exch	KBP5339M	1

In the above table the transformation codes refer to:
1. First difference of the logarithm.
2. First difference.
* Combination of month-on-month inflation rates for the series that ended in December 2008 (CPI: All items - Index 2005=100), and the new series that was measured from January 2008 (CPI: Headline Inflation - Index 2005=100). Data provided by Statistics South Africa.

Table 3: Standard deviations of economic time series

	Std deviation	Std deviation relative to 1960-2011					
code	**1960-2011**	**1960-1969**	**1970-1979**	**1980-1989**	**1990-1999**	**2000-2009**	**2000-2011**
GDP	0.027	1.1	0.81	1.24	1.08	0.77	0.71
CONS	0.029	0.89	1.03	1.31	0.91	0.89	0.83
CDUR	0.122	1.04	0.98	1.45	0.56	0.83	0.86
CSDU	0.055	0.74	1.08	1.15	0.72	1.18	1.11
CNDU	0.028	0.99	0.92	1.02	1.2	0.93	0.87
CSER	0.031	0.79	1	1.52	0.8	0.62	0.6
GOV	0.046	1.32	1.08	0.9	1.03	0.28	0.27
GFCF	0.086	1.04	0.89	1.32	0.88	0.8	0.77
GFCR	0.121	1.2	0.87	1	0.73	1.14	1.14
GFCN	0.124	0.9	0.95	1.12	1.22	0.61	0.58
INV	0.024	1	1.32	1.16	0.74	0.53	0.52
GDE	0.05	1.13	1.11	1.25	0.74	0.59	0.56
EXP	0.065	0.74	0.94	1.29	1.08	1.44	1.33
IMP	0.132	1.17	1.03	1.34	0.61	0.77	0.74
GVAP	0.057	0.84	0.82	0.76	1.65	0.44	0.55
GVAS	0.049	1.26	0.79	1.21	0.93	0.93	0.87
GVAT	0.023	1.13	0.98	1.14	1.01	0.67	0.65
GVA	0.026	1.04	0.76	1.25	1.13	0.79	0.73
EMP	3.474	.	1.3	0.91	0.84	0.98	0.92
WAGE	0.041	.	0.92	0.99	0.93	1.05	1.02
CPI	0.038	.	0.23	1.12	0.7	1.23	1.25
DEF	0.05	1.31	0.88	1.29	0.65	0.56	0.54
PRND	0.289	.	0.66	1.45	0.73	0.99	0.98
PRDU	0.116	0.85	0.89	1.14	1.02	1.05	0.99
PROD	0.124	0.72	0.99	1	0.99	1.51	1.4
LPR	0.038	0.93	0.75	1.29	1.07	1.19	1.23
LCT	0.065	1.1	0.84	1.18	1	0.94	0.9
NOTI	0.009	.	.	.	0.99	1.65	1.54
TBIL	0.008	.	.	1.43	0.78	0.68	0.64
GOVS	0.005	.	.	.	0.75	1.47	1.4
ESK	0.005	0.64	0.73	1.41	1.09	1.73	1.6
EXCH	0.156	.	0.68	1.13	0.52	1.25	1.24

Table 4: Break-point tests for the GDP mean

Break	**Confidence**	p **value**
1967:4	1967:2 - 1968:2	0.00
1976:4	1976:2 - 1977:2	0.00
1981:4	1981:2 - 1982:2	0.00
1992:4	1992:2 - 1993:2	0.05
1997:2	1996:4 - 1997:4	0.00

Table 5: Break-point tests for the GDP variance

Break	**Confidence**	p **value**
1986:1	1985:3 - 1988:1	0.00

Table 6: Percentage change in volatility between the break-points 1981q4 and 1986q1

Variable	Change	Weight	Contribution
GDP	-0.25	.	.
CONS	-0.33	0.54	-0.17
CDUR	-0.00	0.06	-0.00
CSDU	-0.22	0.03	-0.00
CNDU	-0.02	0.27	-0.00
CSER	-0.08	0.16	-0.01
GOV	-0.12	0.19	-0.02
GFCF	0.08	0.17	0.01
GFCR	0.05	0.03	0.00
GFCN	0.35	0.03	0.01
INV	-0.20	.	.
GDE	-0.06	0.98	-0.06
EXP	-0.03	0.19	-0.00
IMP	0.10	0.16	0.02
GVAP	-0.10	0.13	-0.01
GVAS	-0.13	0.25	-0.03
GVAT	-0.07	0.52	-0.03
GVA	-0.17	0.89	-0.15
EMP	-0.42	.	.
WAGE	-0.25	.	.
CPI	0.17	.	.
DEF	-0.25	.	.
PRND	-0.03	.	.
PRDU	-0.03	.	.
PROD	0.03	.	.
LPR	0.36	.	.
LCT	-0.12	.	.
NOTI	.	.	.
TBIL	.	.	.
GOVS	.	.	.
ESK	-0.01	.	.
EXCH	0.34	.	.

Table 7: Break points in mean and variance

	Cond Mean			Cond Variance (break)			Cond Var (trend & break)		
Series	p	break	conf. int.	p	break	conf. int.	p trend	p break	break
GDP	0	1976:4	1976:2 - 1977:2	0	1986:1	1985:3 - 1988:1	0.87	0.01	1986:1
CONS	0	1976:1	1975:3 - 1976:3	0	1984:4	1984:2 - 1986:1	0.51	0	1984:4
CDUR	0.04	1997:1	1996:3 - 1997:3	0	1987:2	1987:1 - 1989:4	0.65	0.01	1987:2
CSDU	0.02	1987:1	1986:3 - 1987:3	0	1984:3	1983:3 - 1987:2	0.12	0	1984:3
CNDU	0	1984:3	1984:1 - 1985:1	0	1988:1	1987:3 - 1989:2	0.99	0	1988:1
CSER	0	1977:1	1976:3 - 1977:3	0	1994:2	1993:4 - 1996:1	0.29	0	1994:2
GOV	0	1992:3	1992:1 - 1993:1	0	1987:3	1987:1 - 1989:2	0.99	0.05	1987:3
GFCF	0	1987:3	1987:1 - 1988:1	0	1988:2	1987:4 - 1989:4	0.96	0.03	1988:2
GFCR	0	1971:3	1971:1 - 1972:1	0.01	1989:2	1987:4 - 1993:2	0	0.08	.
GFCN	0	1992:2	1991:4 - 1992:4	0	2002:2	2002:1 - 2004:1	0.03	0	1996:3
INV	0.48	.	. - .	0	1986:1	1985:3 - 1988:2	0	0.22	.
GDE	0.05	1973:3	1973:1 - 1974:1	0	1995:3	1995:1 - 1997:3	0	0.16	.
EXP	0	2004:2	2003:4 - 2004:4	0.06	.	. - .	0	0	1979:1
IMP	0.03	1973:3	1973:1 - 1974:1	0	1988:2	1987:4 - 1990:2	0.3	0	1988:2
GVAP	0.02	1970:4	1970:2 - 1971:2	0	1996:2	1995:4 - 1998:3	0.11	0	1996:2
GVAS	0	1981:3	1981:1 - 1982:1	0	1978:1	1976:4 - 1980:3	0	0	2003:4
GVAT	0	1970:1	1969:3 - 1970:3	0	1969:4	1969:3 - 1970:4	0	0	1969:4
GVA	0	1976:4	1976:2 - 1977:2	0	1986:3	1986:1 - 1988:3	0.99	0.08	.
EMP	0.07	.	. - .	0.02	1978:1	1977:3 - 1980:3	0.8	0.04	1978:1
WAGE	0	1992:4	1992:2 - 1993:2	0.05	.	. - .	0.98	0.6	.
CPI	0	1982:1	1981:3 - 1982:3	0.92	.	. - .	0.52	0.53	.
DEF	0	1994:1	1993:3 - 1994:3	0.01	1985:4	1985:1 - 1990:2	0	0	1968:4
PRND	0.17	.	. - .	0.13	.	. - .	0	0	1978:4
PRDU	0	1995:2	1994:4 - 1995:4	0	1980:2	1975:2 - 1982:1	0.99	0.27	.
PROD	0.14	.	. - .	0	1993:2	1985:4 - 1994:2	0.93	0.34	.
LPR	0	1994:1	1993:3 - 1994:3	0.88	.	. - .	0.33	0.24	.
LCT	0.02	1992:3	1992:1 - 1993:1	0.5	.	. - .	0.86	0.68	.
NOTI	0	2001:2	2000:4 - 2001:4	0.23	.	. - .	0.93	0.42	.
TBIL	0.85	.	. - .	0	1986:3	1986:1 - 1987:4	0	0	1998:2
GOVS	0	2001:1	2000:3 - 2001:3	0.25	.	. - .	0.99	0.69	.
ESK	0.01	2002:1	2001:3 - 2002:3	0	1975:1	1965:4 - 1975:4	0	0	1990:1
EXCH	0.05	1985:4	1985:2 - 1986:2	0.05	1998:2	1992:1 - 2000:3	0.46	0.05	1998:2

Table 8: Common break-points in the variances of VAR residuals

Variable	**# variables**	**QLR** p	**Break**	**Conf. interval**
consumption, gov exp, GFCF, exports, imports	5	0.00	1988:1	1987:2 - 1988:3
GVA primary, GVA second, GVA tertiary	3	0.00	1970:3	1969:3 - 1971:2
cons durable, cons semi-dur, cons non-dur, cons services	4	0.00	1987:1	1986:1 - 1988:1
gdp, gdp deflator, cpi, tbil, wages, labour prod., exch. rate	7	0.03	1988:1	1987:1 - 1989:1

B Figures

Figure 1: South African Business Cycle

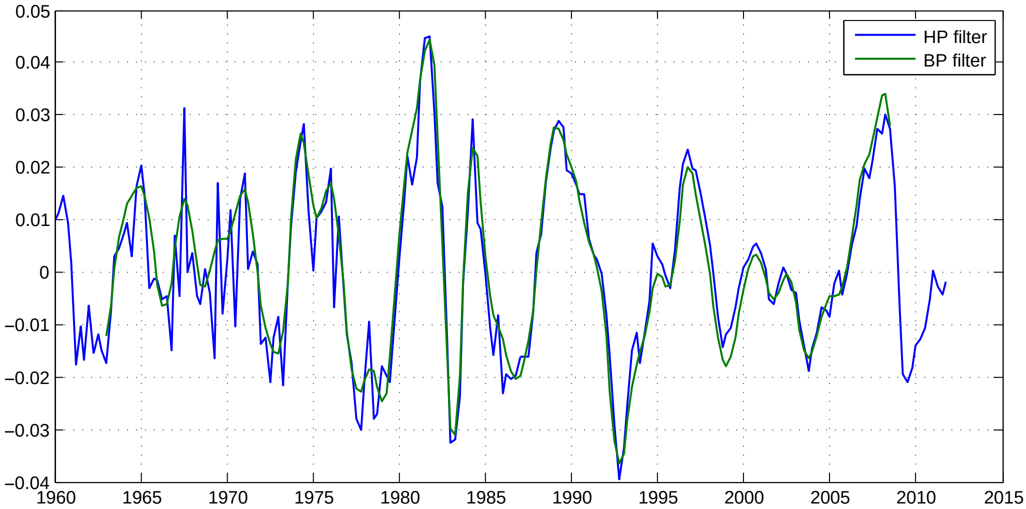

Figure 2: Time varying standard deviations of South African GDP

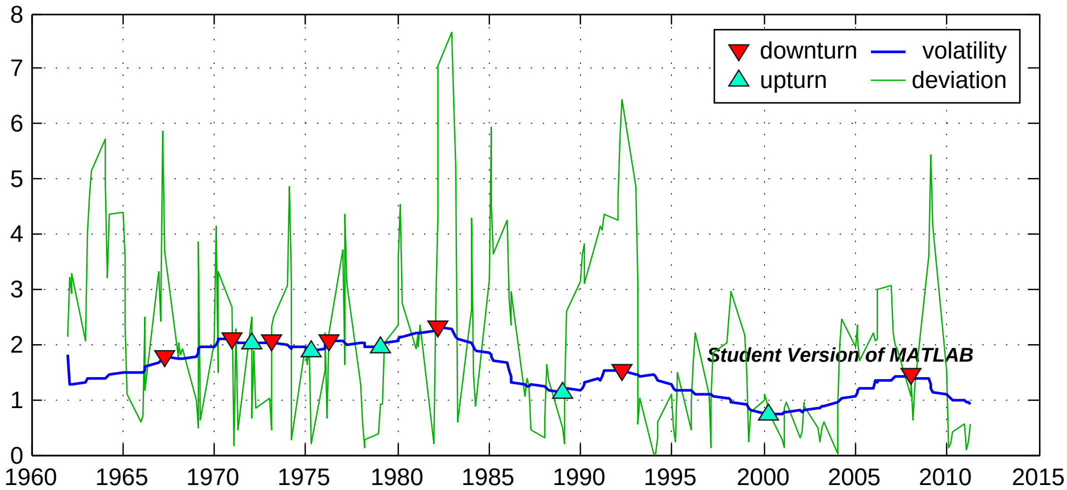

Figure 3: Time-varying stochastic volatility and deviations (page 1)

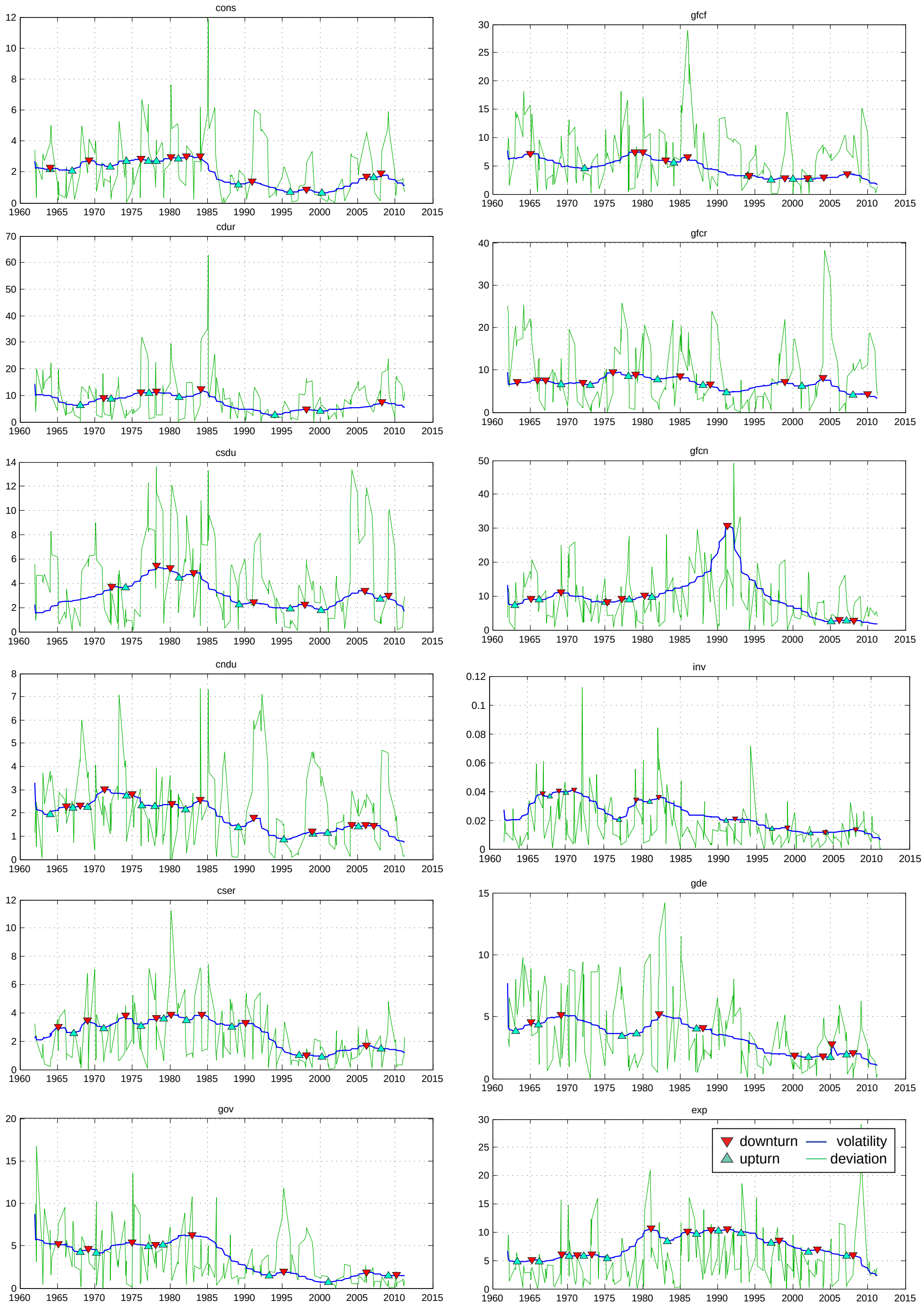

Figure 4: Time-varying stochastic volatility and deviations (page 2)

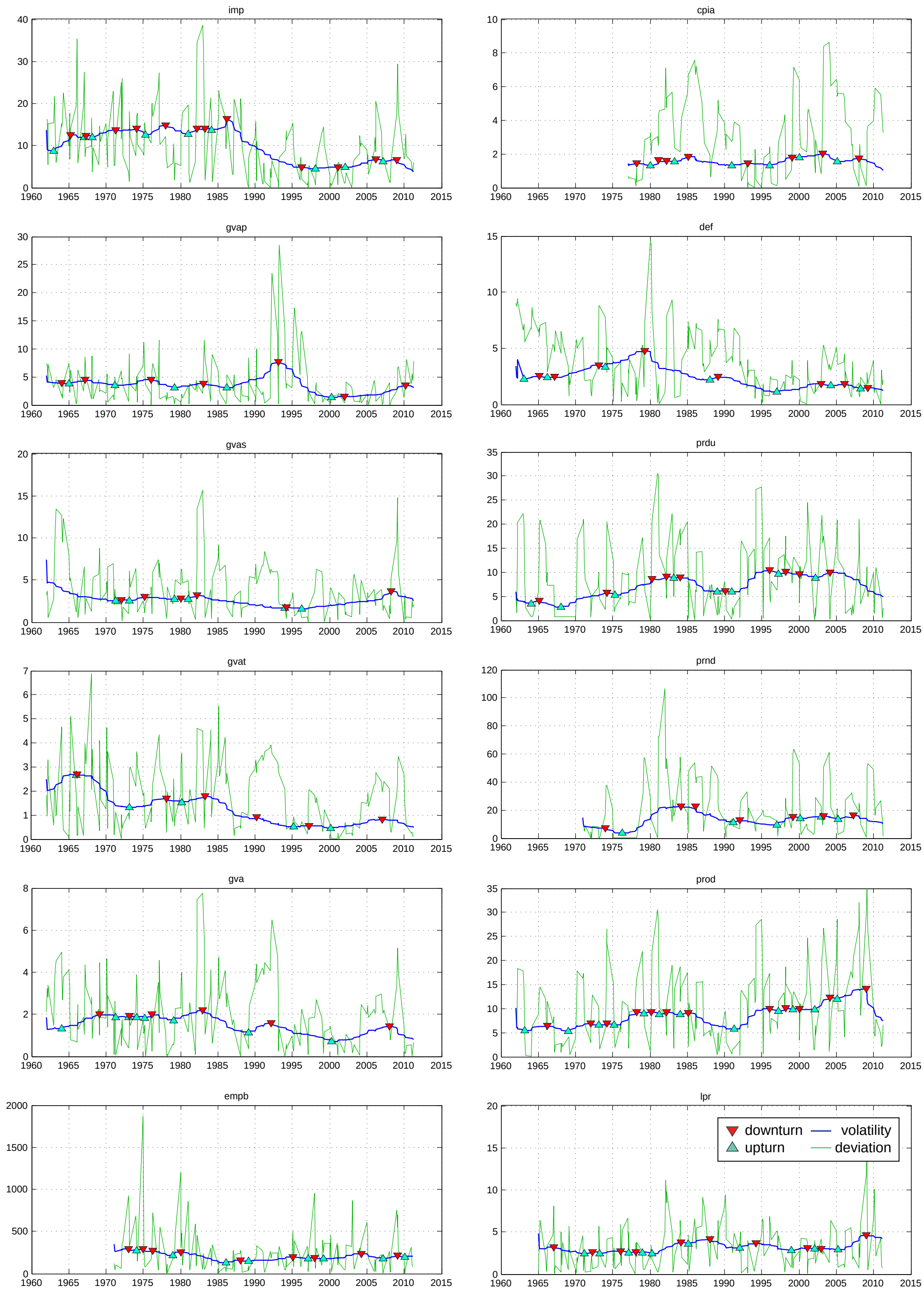

Figure 5: Time-varying stochastic volatility and deviations (page 3)

Figure 6: CUSUM test - GDP mean

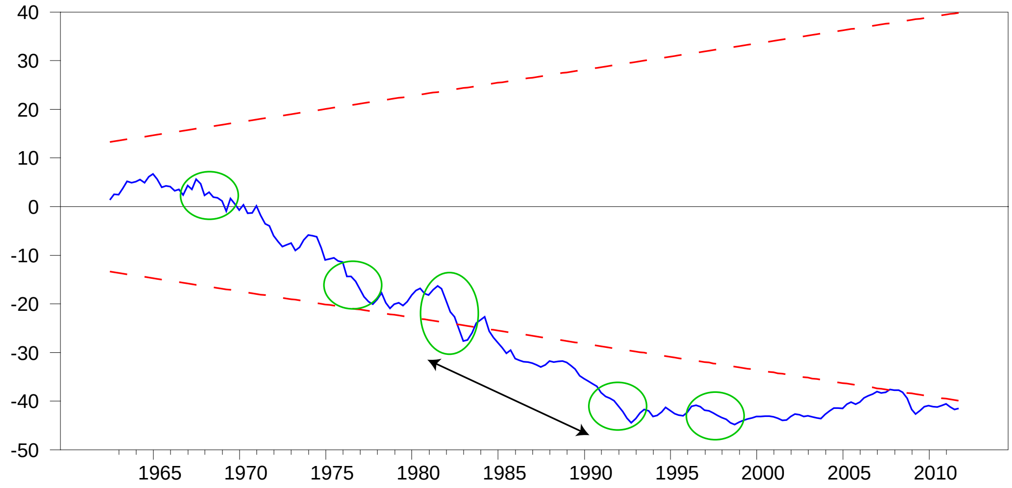

Figure 7: CUSUM test - GDP volatility