WORKING PAPER – July 2021

School of Economics and Finance, University of the Witwatersrand

A cross-country analysis investigating the impact of the 2008-09 Financial Crisis on the conduct of monetary policy

by

Daniella Lamparelli and Kenneth Creamer

Abstract

Taylor Rule analysis is utilised to enable an analysis of how the 2008 Financial Crisis impacted on the conduct of monetary policy across various countries. Structural Break Analysis and Markov Switching (MS) Regressions are used in order to identify breaks and changes in the conduct of monetary policy as result of the Crisis. The study finds evidence of Crisis-related changes in monetary policy conduct in South Africa, as well as in the US, the UK, the Euro Area (the ECB), Colombia, Peru and South Korea. On the other hand, the results for Brazil, Mexico and Israel do not show conclusive differences in monetary policy conduct in the pre-Crisis and post-Crisis periods. Along with South Africa, there are only two other countries, namely Brazil and Mexico, whose smoothing parameters are larger in the post-Crisis period. Four out of the ten countries place a lower weight on inflation post-Crisis. Six central banks reduce their weighting on the output gap after the Crisis.

Introduction

In this study Taylor Rule regressions are used to examine the monetary policy conduct of ten central banks: that of, South Africa, Brazil, Colombia, Mexico, Peru, Israel, the Republic of Korea, the United Kingdom (UK), the United States (US) and the European Central Bank (ECB) for the Euro Area. Particular focus is placed on South Africa and how its monetary policy behaviour compares to that of the other countries in the sample. In accordance with the existing literature, two econometric techniques, namely Structural Break Analysis and Markov Switching (MS) Regressions, are used in order to identify whether there were changes in monetary policy conduct after the 2008 Financial Crisis.

Literature on the conduct of monetary policy relevant to this study is extensive. Several studies have explored the conduct of central bank actions when responding to this Crisis (see Frappa & Mésonnier, 2009: Taylor, 2009). However, there is a limited selection of studies that empirically compare the conduct of monetary policy before and after the 2008 Financial Crisis at a country level.

Coco and Viegi (2020) examined how the monetary policy stance and credibility of the South African Reserve Bank (SARB) evolved over the period 2000 to 2018. Using a variety of open-economy Taylor Rule specifications to estimate the SARB's reaction function, the authors found that the SARB

was better able to control inflation expectations after 2009 (Coco & Viegi, 2020). At the same time, policy rate changes became smaller and more infrequent, and the monetary policy response to the output gap was lower after the crisis than before it (Coco & Viegi, 2020).

In addition, Kabundi and Rapapali (2019) investigated the differences in the transmission of monetary policy in South Africa before and after the global Financial Crisis. The authors used a Bayesian vector autoregressive model and found that there was a considerable change in the transmission of monetary policy after the 2008 Crisis: the impact of monetary policy on output was reduced and the impact on inflation became statistically insignificant after 2008 (Kabundi and Rapapali, 2019).

In this study, monetary policy is narrowly defined as focusing on the process of stabilising economic activity through the setting of policy interest rates by monetary authorities. Incorporated into this definition is the impact of various factors which influence the setting of such policy rates – a study which is made tractable by the use of Taylor Rule analysis. Beyond the scope of the current study are the wider impacts of crises on the roles and responsibilities of monetary policy authorities more generally, such as how the Financial Crisis led to a broadened mandate of monetary authorities from a relatively narrow focus on inflation targeting to one that includes responsibilities for macroprudential monitoring and management (De Nicolò et. al., 2012). Also beyond the scope of the current study is any cataloguing or analysis of the increased use of unconventional monetary policies – and related bond market interventions – by monetary authorities (Strohecker, 2020).

Taylor-type Monetary Policy Rules

A common tool used to evaluate the conduct of monetary policy in the reviewed literature is the monetary rule specified by Taylor (1993) (the "Taylor Rule"), together with adjustments put forth by Taylor (1999), Clarida et. al. (2000) and others. The original Taylor Rule can be specified as follows:

$$i_t = \pi_t + r_t^* + \beta_\pi(\pi_t - \pi_t^*) + \beta_y Gap_t + u_t \quad (1)$$

where i_t is the central bank interest rate, or policy rate; π_t is the inflation rate; r_t^* is the neutral or target real interest rate; π_t^* is the central bank's target inflation rate; Gap_t represents the output gap or deviation of actual output from potential output; and u_t is a disturbance error term that captures exogenous shocks. In the original specification, $\beta_\pi = \beta_y = 0.5$. This assumption implies that central banks place equal weightings on deviations of the price level and output from their target levels when setting the policy rate. In addition, when both the inflation rate and output are at their target levels (or "in equilibrium"), the real interest rate is assumed to be constant at 2 percent (i.e.: $r_t^* = 2$).

Five years after his influential paper, Taylor (1998) revised the monetary policy rule to include a stabilising condition on the size of the coefficient of the inflation gap. He concluded that, while the coefficients of inflation and output should both be positive, central banks must react by more than one-to-one to deviations in the inflation rate in order to achieve the desired result of steering the economy back to the desired long-run equilibrium (Taylor, 1998). This condition is now known as the Taylor Principle and can easily be incorporated into equation (1).

Let $\beta_0 = \pi_t + r_t^*$ be the intercept, a constant. Then (1) becomes:

$$i_t = \beta_0 + (1 + \beta_\pi)(\pi_t - \pi_t^*) + \beta_y Gap_t + u_t \quad (2)$$

The Taylor Principle requires that $(1 + \beta_\pi) > 1$ for stability, such that increases in inflation are met with a more than one-to-one response from the policy rate. Furthermore, the Taylor Principle is argued to be an important condition for all central banks who aim for price stabilisation, regardless of the particular policy rule being followed (Greenspan, 2004: Mishkin, 2011).

Clarida et. al. (2000) argued that the original monetary rule did not accurately represent central banks' decision-making processes. Without modifications, the rule does not capture either the possible randomness of the central bank's actions, or the unpredictable movements of interest rates interacting with financial markets. To account for these, Clarida et. al. (2000) built an interest-smoothing parameter, ρ, into the model. This captures the tendency of central banks to adjust their interest rates in a sequence of small adjustments, so as to close the gaps incrementally over time rather than opt for a full interest rate adjustment that could shock financial markets into destabilising the economy. Therefore, the central bank chooses its current policy rate, i_t, according to a weighted function of the previous rate, i_{t-1}, and the gaps observed in the fundamental rule, i_t^*:

$$i_t = \rho i_{t-1} + (1 - \rho) i_t^* \quad (3)$$

where ρ is the degree of interest rate smoothing, typically expected to lie between zero and one (Perruchoud, 2009: Drakos & Kouretas, 2015).

By rewriting (2) in terms of (3) and collecting constants[1]:

$$i_t = \alpha_0 + \rho i_{t-1} + (1 - \rho)\left[\alpha_\pi \pi_t + \alpha_y Gap_t\right] + \nu_t \quad (4)$$

1 $\alpha_0 = (1 - \rho)[\beta_0 - \beta_\pi \pi_t^*]$.

The monetary rule in equation (4) makes it possible to examine whether a central bank responds instantaneously to deviations from equilibrium (where ρ equals zero), or more inertially (where ρ is closer to one) (Clarida et. al., 2000). Specifically, a decrease in ρ would indicate increasing responsiveness of central banks to changes resulting from the impact of a global crisis, and an increase in ρ would indicate decreasing responsiveness.

Ball (2000) put forth a new modification of the Taylor Rule that included the real exchange rate as an additional independent variable in the policy rate specification. If a real exchange rate variable, RER_t, is included in equation (1) and the same modification processes as outlined in sections 3.2 and 3.3 are followed, some basic algebraic simplifications yield:

$$i_t = \varphi_0 + \varphi_1 i_{t-1} + \varphi_\pi \pi_t + \varphi_y Gap_t + \varphi_R RER_t + \varepsilon_t \quad (5)$$

where the coefficient of the lagged interest rate, φ_1 now represents the interest smoothing parameter.

Interest-rate smoothing implies that central banks aim to close a fraction of the gaps at a time, over several short runs. This means that a central bank's long-run coefficient on inflation can be calculated as $\varphi_\pi/(1-\varphi_1)$ which, according to the Taylor Principle, must be positive to achieve long-run price stability (Woglom, 2003).

Econometric Methodology

This article makes use of two econometric techniques to check for a change in monetary policy conduct: Structural Break Tests and MS regressions.

Structural break tests are used to identify the location of structural changes and non-stationarity in time series data. The procedure developed by Brown et. al. (1975) is used to test for parameter stability in the monetary policy rules of each country. This procedure is preferred over others, such as the Chow (1960) test, because it allows testing for multiple breaks, the dates of which do not need to be known beforehand. The Brown et. al. (1975) procedure involves two tests: the cumulative sum (CUSUM) test and cumulative sum of squares (CUSUMQ) test. The null hypothesis of both tests is that the regression coefficients and their variances remain constant, while the alternative is that there is at least one structural break over the period.

These tests are used to determine whether a structural break occurred during the Financial Crisis, identified by the Federal Reserve Bank of St Louis (2020) to have started in February 2007 and ended

in April 2011. If a break is found, regressions of the Taylor Rule (equation (5)) are run for each of the time periods on either side of the break. Differences in the coefficients of the policy rules between the periods indicate if – and how – the conduct of monetary policy has changed: for instance, how the weightings on inflation and the output gap differ between the two periods. Thereafter, Wald tests are conducted on each pair of coefficients to confirm whether the differences are statistically significant and, therefore, whether any structural break is statistically significant.

The pre- and post-structural break periods are used as approximations for the pre- and post-Crisis periods, respectively. Given that each country was impacted by (and then responded to) the 2008 Financial Crisis at different times, it would not be accurate to select a break date *a priori* and apply it to all countries. Instead, structural break testing is used to identify whether, and when, break dates can be identified for each country based on its own historical data.

To complement the study's structural break analysis – and in order to check the robustness of the break-test results – MS regression methodology is used to characterise parameter changes in the time series data. As a robustness check, the MS regression methodology can confirm the dates of the structural breaks. Furthermore, since the presence of structural breaks does not necessarily imply that a regime change has occurred, the MS regression allows an assessment of whether identified structural breaks are indeed associated with a change in regime.

Given an unobserved state variable, S_t with K possible states/regimes, the generalized MS regression model framework can be laid out as follows (Sánchez, 2015):

$$\boldsymbol{y}_t = \boldsymbol{\mu}_{S_t} + \boldsymbol{x}_t \cdot \boldsymbol{\alpha} + \boldsymbol{z}_t \cdot \boldsymbol{\beta}_{S_t} + \boldsymbol{\varepsilon}_{S_t,t} \tag{6}$$

where $\boldsymbol{y}_t$ is the vector of endogenous variables;

$\boldsymbol{\mu}_{S_t}$ is a state-dependent intercept;

$\boldsymbol{x}_t$ is a vector of exogenous variables with state-invariant coefficients, $\boldsymbol{\alpha}$; and

$\boldsymbol{z}_t$ is a vector of exogenous variables with state-dependent coefficients, $\boldsymbol{\beta}_{S_t}$.

The error terms $\varepsilon_{S_t,t}$ are assumed to be independent and identically normally distributed. That is, $\varepsilon_{S_t,t} \sim i.i.d\ N(0, \sigma^2)$ (Sánchez, 2015).

Following Drakos and Kouretas (2015), a two-state MS regression model is estimated, and the parameters are allowed to switch between two states, $S_t = \{1,2\}$. The analysis is extended to an open-

economy Taylor Rule, akin to that in equation (5), but now allowing the coefficients to be state-dependent, as in Murray et. al. (2015):

$$i_t = \gamma_{0,S_t} + \gamma_{1,S_t} i_{t-1} + \gamma_{\pi,S_t} \pi_t + \gamma_{y,S_t} Gap_t + \gamma_{R,S_t} RER_t + \varepsilon_{t,S_t} \quad (7)$$

Changes in the coefficients of the policy rule equation are what constitute a regime change (Creel and Hubert, 2010). Therefore, by comparing the coefficient weightings on the inflation and output gaps in each regime, it is possible to evaluate whether the conduct of monetary policy differs between regimes. Once again, Wald tests will measure the significance of the difference between coefficients.

Data used in the study

The data collected for this study are monthly data spanning the period January 2000 to June 2020. This period is deemed to be sufficient for the analysis as it covers the period dubbed the Great Moderation (from 2000 to 2008), the Global Financial Crisis (from 2008 to 2011), the period of secular stagnation from 2011 to 2019, as well as the beginning of the COVID-19 Crisis in 2020 (Federal Reserve Bank of St Louis, 2020). The sources for the data are the official central bank websites for each country, as well as the Federal Reserve Bank of St Louis (2020) Economic Research website. Based on which data were readily available in compatible format, the central banks included in the sample are those of South Africa, Brazil, Colombia, Mexico, Peru, Israel, the Republic of Korea, the United Kingdom (UK), the United States (US) and the European Central Bank (ECB) for the Euro Area.[2] Like South Africa, all central banks in the sample (except that of the US) follow an inflation-targeting framework and have done so since the early 2000s or earlier (Jahan, 2017). The US has been included due to its systemic importance in the global economic system.

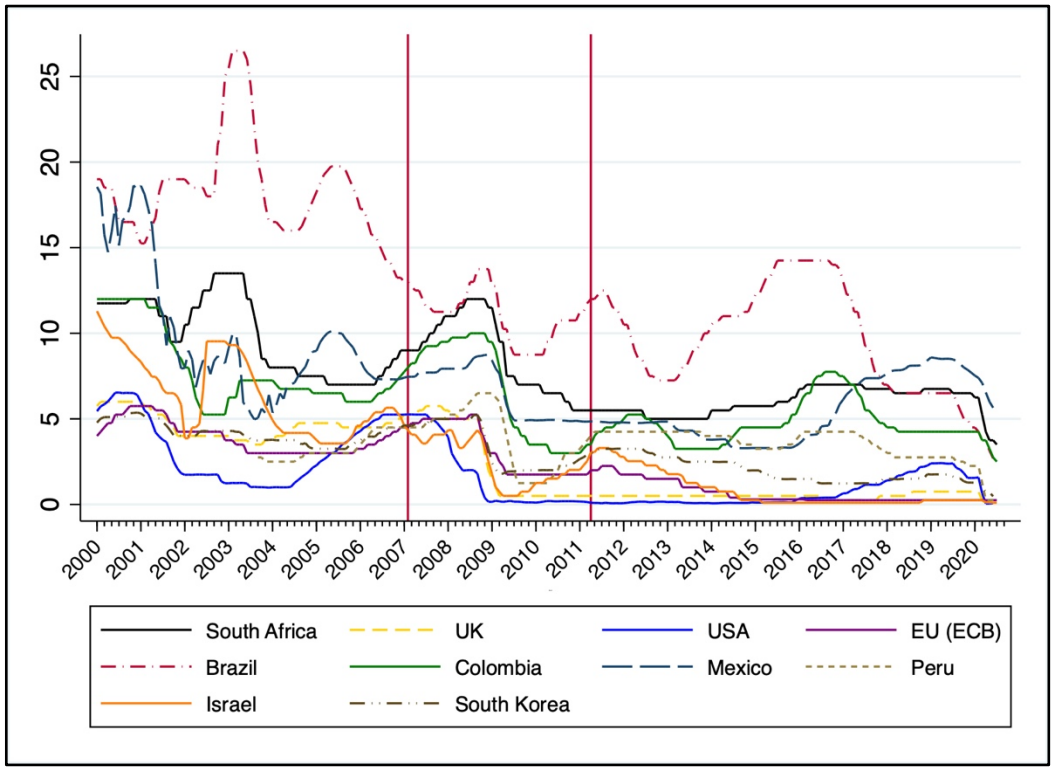
The variables required for a regression of the Taylor Rule expressed in equation (5) are:

- the central bank monetary policy interest rate;
- the monthly Consumer Price Index (CPI) for all items (or all items in urban areas);
- the monthly real effective exchange rate index; and
- the monthly real total volume of production in manufacturing index.

2 The raw data required for this study have been obtained for the whole period, with the exceptions of Peru (for which policy rate data could only be obtained from September 2003 onwards), and South Africa (for which CPI and output data were not available after April 2020 at the time of writing this paper).

Figure 1 presents the evolution of the ten central bank policy rates over the sample period. The two red vertical lines indicate the start (February 2007) and end (April 2011) of the Crisis.[3] All ten central banks decreased their policy rates during the Financial Crisis, with the US Federal Reserve being the first to do so, beginning in August 2007. Thereafter, the drops in policy rates are staggered over time. Outside of the US, the first central banks to respond are those of Israel, the UK, South Korea and the EU in mid 2008. The developing countries, namely South Africa and the South American countries, responded later, with their central banks lowering rates in late 2008 and early 2009.

Figure 1: Central Bank Policy Interest Rates, 2000 – 2020



Data Source: Central Bank websites and the St Louis Federal Reserve

It is evident from Figure 1 that the developed countries in the sample entered the recession – and their monetary authorities responded – earlier than the developing countries. While developing countries may have seen relatively larger policy rate cuts in a shorter time span, developed countries' rates were generally lower to begin with and the magnitudes of their rate cuts were constrained by the zero lower bound.[4]

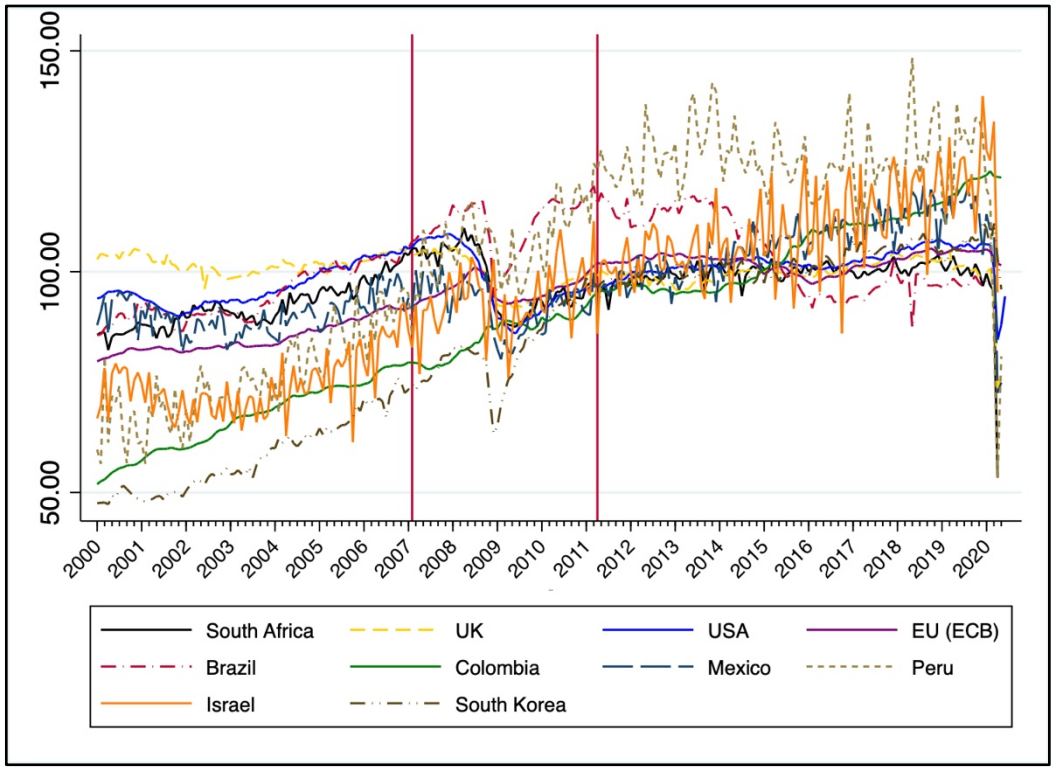
Figure 2 presents the real monthly manufacturing output index for the ten countries. The figure shows that most countries were experiencing sustained output growth in the years leading up to 2007, a

3 For purposes of presenting the relevant descriptive data, the start and end dates of the Crisis used in this study follows the determination on this matter by the Federal Reserve Bank of St Louis (2020).

4 Although some central banks – not included in the current study – implemented negative nominal rates.

feature consistent with the growth characteristics of the period known as the Great Moderation. With the exception of Colombia, all countries experienced a dramatic drop in output during 2008.

Figure 2: Monthly Output, 2000 – 2020

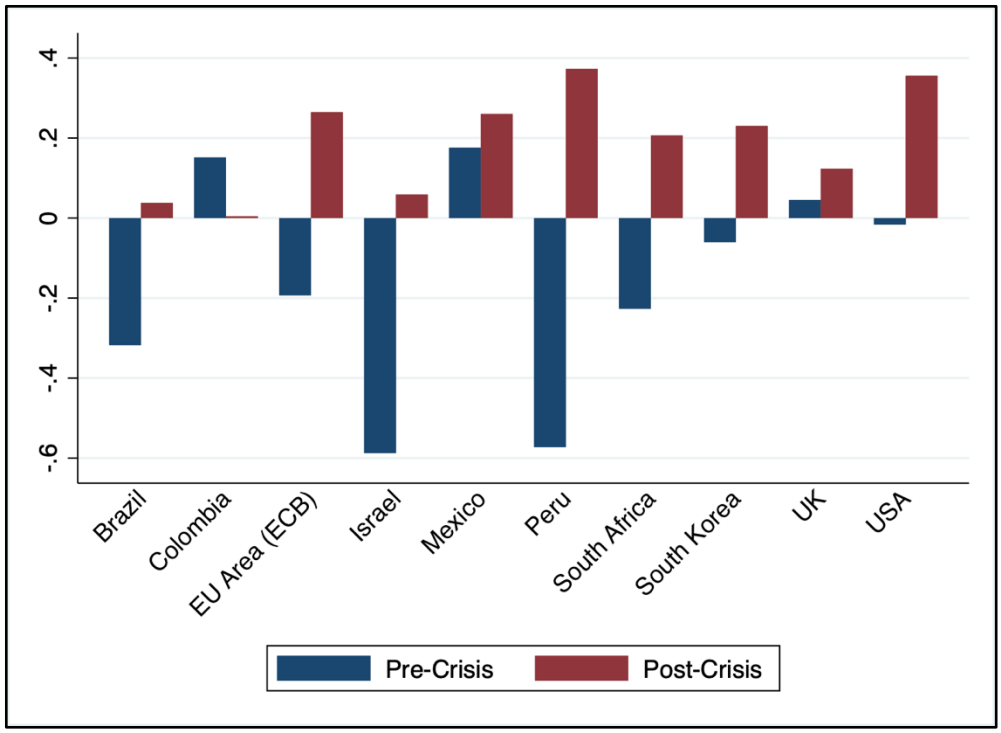


Data Source: Central Bank websites and the St Louis Federal Reserve

Notably, after recovering from the recession, the sample countries entered a prolonged period of output stagnation, or secular stagnation, until experiencing the drop in output resulting from the COVID-19 Crisis starting in March/April 2020. The data in Figure 2 were used to construct the output gap variable for the Taylor Rule.

Figure 3 shows the mean output gap for each country, pre-Crisis (January 2000 – January 2007) and post-Crisis (May 2011 – June 2020). Most countries in the sample – with the exceptions of Colombia, Mexico and the UK – see a change from having a negative average output gap in the pre-Crisis period to having a positive average output gap in the post-Crisis period. This means that pre-Crisis, actual output was below its potential value on average, while, post-Crisis, actual output was above its potential value on average in these countries. Negative output gaps are typically associated with recessions, while positive output gaps are typically associated with expansions. The observations in Figure 3 (a mean negative output gap during the 2000 – 2007 expansionary period) therefore seem, at first, to be counterintuitive. However, the result is a consequence of the decline in potential output resulting from the 2008 Crisis and the lengthy period of stagnation that followed it.

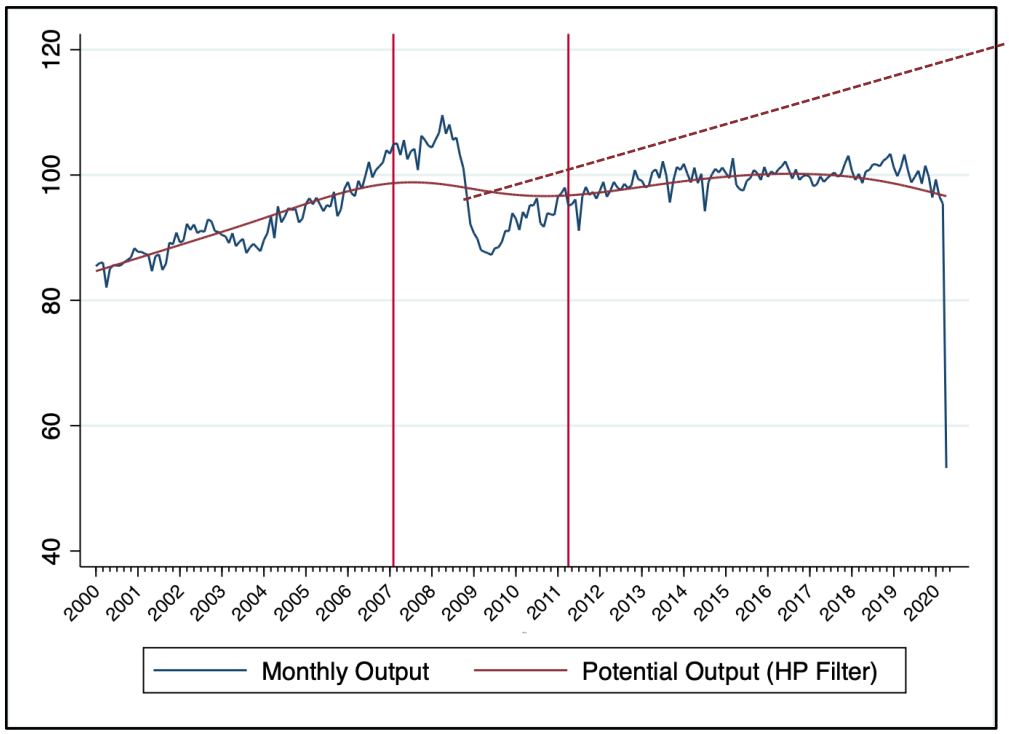
Figure 3: Mean Output Gap, Pre- and Post-Financial Crisis



Data Source: Central Bank websites and the St Louis Federal Reserve

This is clearly indicated in the diagrammatic representation of South Africa's output gap over the whole 20-year period, which is shown in Figure 4. The smooth dark red line shows South Africa's trend potential output, and the blue jagged line shows the country's actual monthly output. The difference between actual output and potential output is the output gap.

Figure 4: Monthly Output and Potential Output for South Africa, 2000 – 2020

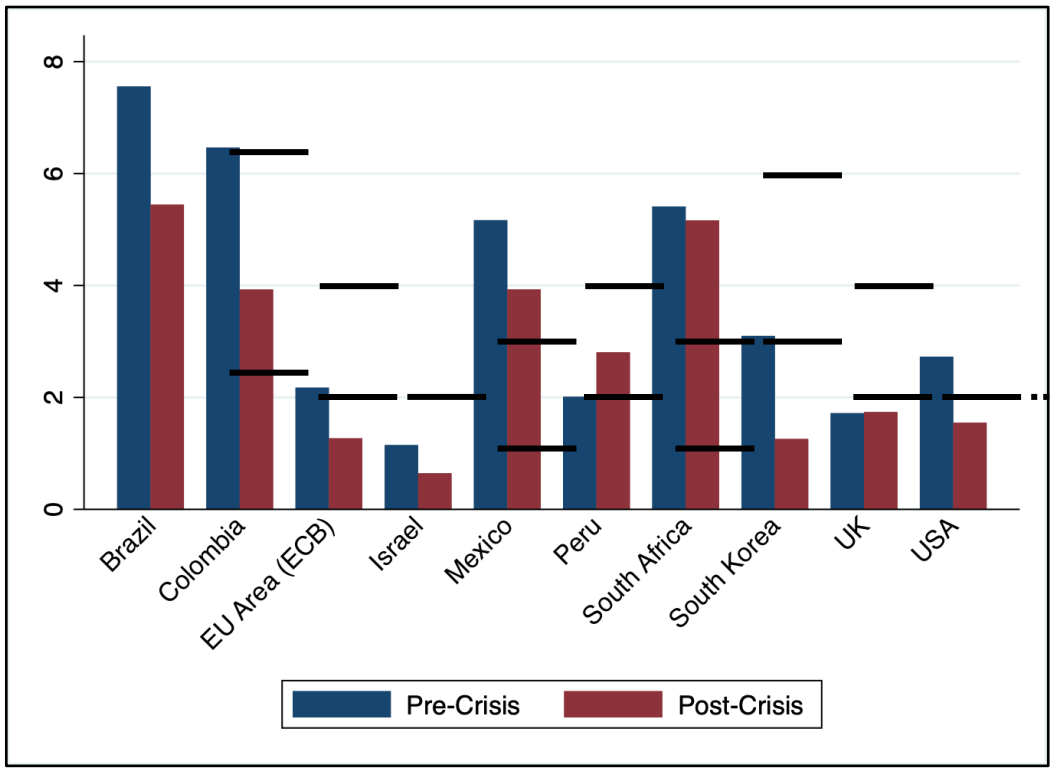


Data Source: South African Reserve Bank

Figure 4 shows that, on average, actual output was indeed below its potential level during the early 2000s, despite the overall economic growth and rising potential output. According to the diagram, the economy began to "overheat" in 2006 when output rose well above its potential level and continued to rise until the "crash" in 2008/9. Figure 4 also clearly illustrates the secular stagnation in the post-Crisis period, as well as the dramatic drop in March/April 2020. The loss of potential output is illustrated by the dark red dashed line in Figure 4, which represents the long-term trend of potential output that the economy had followed in the years leading up to 2008, compared to the trend actually followed (i.e. the smooth dark red line).

Figure 5 shows the mean monthly inflation for each country, pre-Crisis (January 2000 – January 2007) and post-Crisis (May 2011 – June 2020). The black horizontal lines in Figure 5 indicate the upper and lower bounds of each country's inflation target (a single line indicates a point target).[5] With the exceptions of the UK and Peru, all countries see lower average inflation rates in the post-Crisis period than in the pre-Crisis period.

Figure 5: Mean Monthly Inflation, Pre- and Post-Financial Crisis



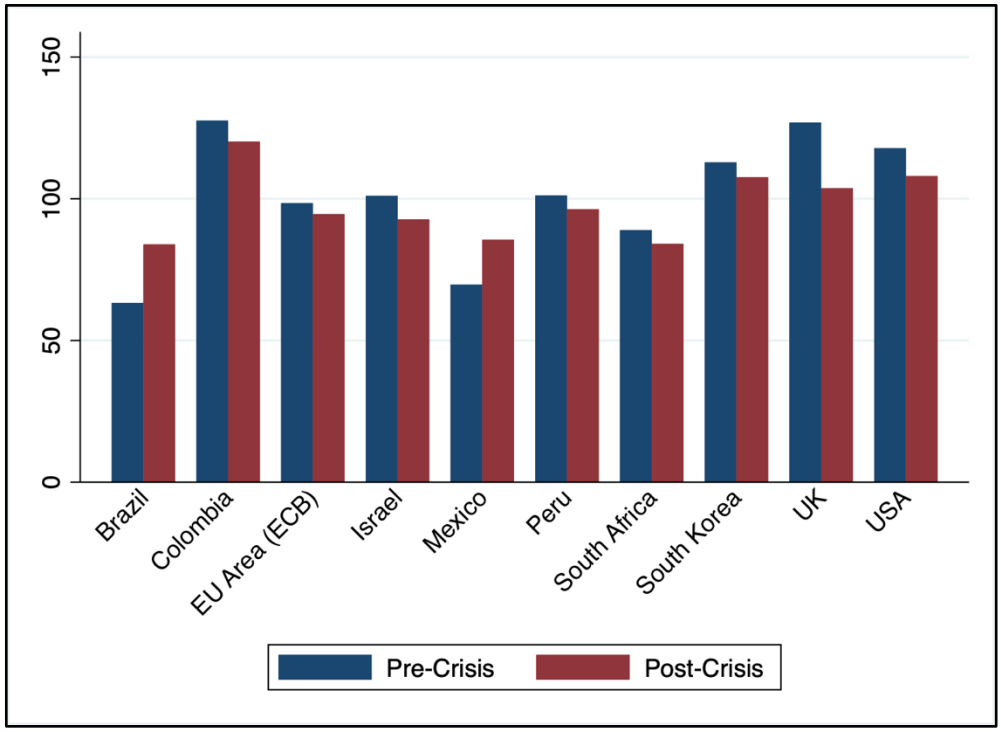
Data Source: Central Bank websites and the St Louis Federal Reserve, and Jahan (2017).

5 Although the US Federal Reserve is not an inflation-targeting central bank, it does aim to keep inflation at 2% over the long term, indicated by the dashed black line in Figure 5 (Federal Reserve Bank of St Louis, 2020).

Figure 6 shows the mean REER for each country, pre-Crisis and post-Crisis. The REER is a measure of trade competitiveness, as it measures the value of the local currency relative to a weighted average of foreign currencies. An increase (decrease) in the REER indicates a local currency appreciation (depreciation), such that local exports become less (more) competitive. Figure 6 indicates that the currencies of Brazil and Mexico have been stronger on average since the 2008 Crisis, while the other currencies have been, on average, relatively weaker.

Changes in the REER are captured by the RER, which is the variable that enters the Taylor Rule.[6] Figure 7 shows the mean RER for each country, pre-Crisis and post-Crisis. Notably, Figure 7 shows that the South African Rand saw more appreciation, on average, before the Crisis than afterwards. The RER is included so as to account for the inflationary effects of exchange rate changes, for which central banks must account when trying to achieve long-run local price stability (Ball, 2000).

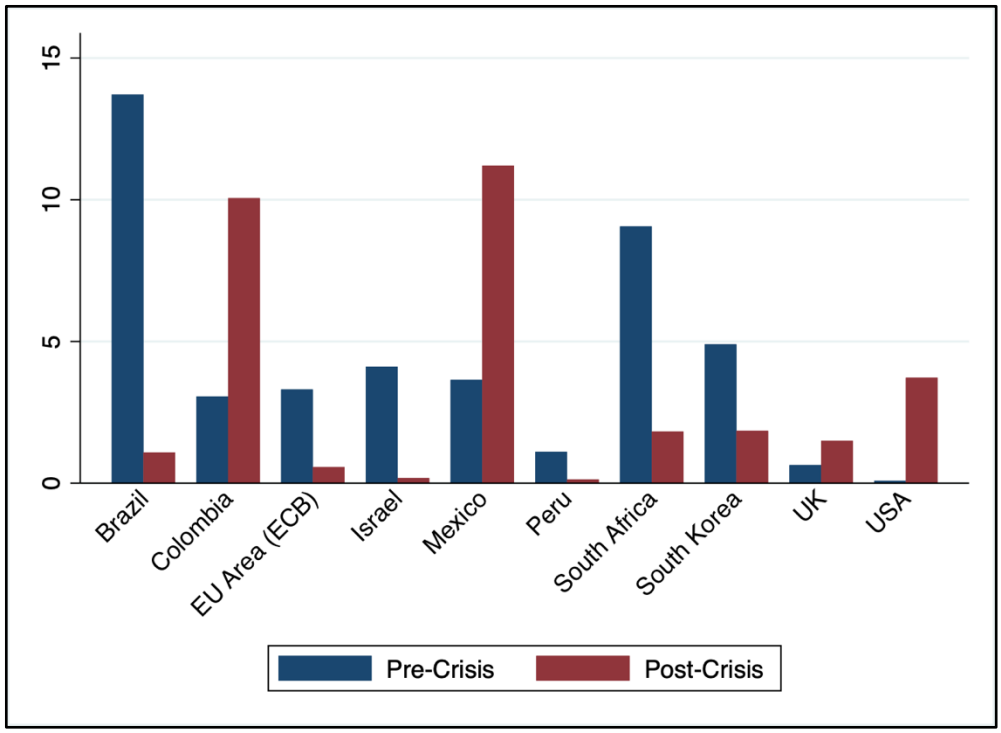
Figure 6: Mean Real Effective Exchange Rate, Pre- and Post-Financial Crisis



Data Source: Central Bank websites and the St Louis Federal Reserve.

Figure 7: Mean Real Exchange Rate Changes, Pre- and Post-Financial Crisis

6 Recall that an increase in RER is an appreciation of the local currency.

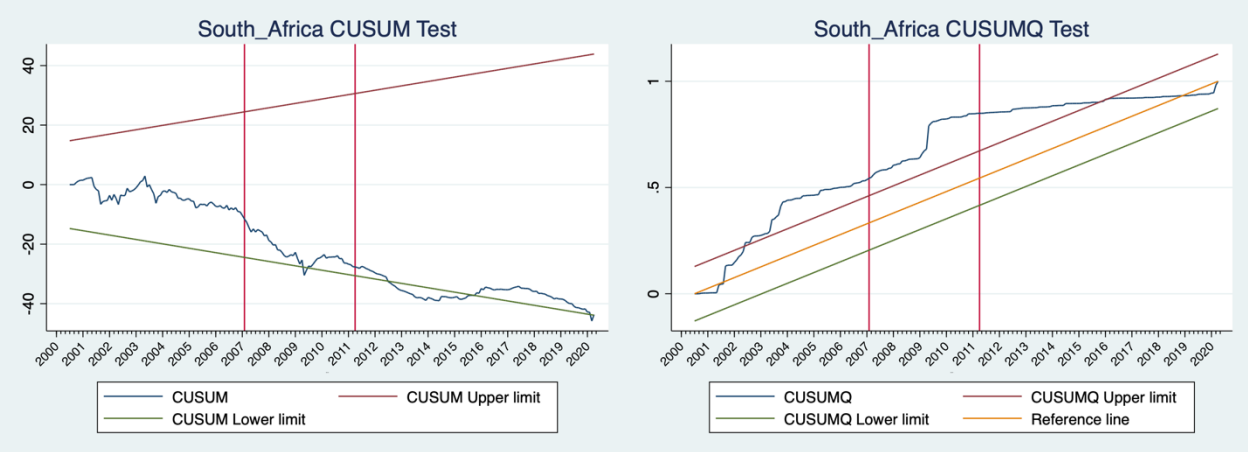


Data Source: Central Bank websites and the St Louis Federal Reserve.

Discussion of Results

The graphical results of the CUSUM and CUSUMQ tests conducted over the January 2000 to June 2020 period for South Africa are presented in Fig. 8. The two vertical red lines in each graph indicate the start (February 2007) and end (April 2011) of the Crisis, as determined by the Federal Reserve Bank of St Louis (2020). For both the CUSUM test and the CUSUMQ tests, the upper and lower limits demarcate a 95% confidence interval. That is, a drifting of the CUSUM or CUSUMQ measure outside of these limits indicates a rejection of the null hypothesis (of no structural break) at the 95% confidence level. The significance of the break can also be evaluated by a Wald test that has a null hypothesis of no structural break at that date.

Figure 8: Structural Break Tests for South Africa



Notably, all ten countries in the sample exhibit at least one structural break during the twenty-year period, and seven of the countries exhibit statistically significant structural breaks during the Financial Crisis. Mexico, Israel and Brazil do not appear to experience structural breaks during the Crisis, but do experience a structural break in 2001, 2002 and 2003, respectively. These results corroborate those of de Medeiros et. al. (2016), who identified Brazil's most significant structural break to have occurred in 2003. However, unlike a finding of the de Medeiros et. al. (2016) paper, the current study does not find that Brazil experienced a structural break in 2008.

This study makes use of the dates identified for the structural breaks in each country (as listed in Table 1) to compare the conduct of monetary policy before and after the Financial Crisis. This is done by conducting two separate regressions for each country on either side of the dates of the identified structural breaks.

Table 1: Statistical significance of estimated break dates

	January 2000 to June 2020 Estimated break date	Wald test Prob > chi2	January 2004 to June 2020 Estimated break date	Wald test Prob > chi2
South Africa	June 2009	0.0283**	June 2009	0.0253**
United States	January 2008	0.0116**	June 2008	0.0000***
United Kingdom	November 2008	0.0000***	November 2008	0.0000***
Euro Area	September 2008	0.0086***	September 2008	0.0167**
Brazil	February 2009	0.1960	September 2006	0.3039
Mexico	February 2009	0.2122	January 2006	0.7192
Peru	February 2009	0.0002***	February 2009	0.0001***
Colombia	February 2009	0.0030***	February 2009	0.0000***
South Korea	October 2008	0.0001***	October 2008	0.0000***
Israel	October 2008	0.0779*	October 2008	0.0916*

*** p<0.01, ** p<0.05, * p<0.1

Table 2 presents a summary of the results of the Taylor Rule regressions for all ten countries, for both the pre- and post-Crisis (structural break) periods. The structural break for South Africa is located in June 2009 and is significant at the 5% level. As reported in Table 2, for South Africa, the Taylor Rule's coefficients for inflation and the output gap have the expected signs both pre- and post-crisis. This is not the case for the coefficient on the RER, which is positive (while its expected sign was negative) although statistically insignificant.

South Africa's smoothing parameter is positive in both periods but is slightly larger in the post-Crisis period, after the structural break, although the difference is not significant according to the Wald test. The high weighting on the previous period's policy rate suggests that the SARB acts somewhat more inertially in the post-Crisis period, choosing to respond to inflation, output and exchange rate changes more slowly over time.

The coefficient on inflation is statistically insignificant in the pre-Crisis period, but doubles in magnitude and becomes highly significant at the 1% level in the post-Crisis period. At the same time, the coefficient on the output gap decreases post-Crisis but remains statistically significant at the 1% level in both periods. This result aligns with those of Coco and Viegi (2020) and confirms the *a priori* expectation that the central bank has placed a greater focus on inflation and a lesser focus on the output gap since 2009. Indeed, the lower volatility of the inflation rate may reflect the SARB's efforts to keep inflation stable post-Crisis. This falls in line with the SARB's inflation-targeting mandate, although the absence of price shocks in this period would also have played a role. However, the difference in pre- and post-Crisis coefficients is only significant for the output gap, with the Wald test being significant at the 1% level. This suggests that the change in monetary policy conduct evident in the results is primarily rooted in the SARB's changed response to the output gap.

These results provide evidence that the change in monetary policy transmission for output observed by Kabundi and Rapapali (2019) occurs simultaneously with changes in monetary policy conduct. That is, the reduced impact of monetary policy on output after the Crisis appears to take place at the same time as the central bank placing a reduced weighting on the output gap in its post-Crisis monetary rule. However, as noted, there are numerous supply-side factors that have also contributed to the persistently low growth of output since the 2008 Financial Crisis. During this period of secular stagnation, the SARB has been less assertive in using the policy interest rate instrument to stimulate

demand, represented by the smaller coefficient on the output gap (even as the output gap has been reported as being positive, on average, primarily due to the fall in potential output post-Crisis).

With regard to inflation, the study shows that the SARB reacts relatively more strongly to inflation post-Crisis – a result which does not, at first glance, align with the statistically insignificant impact of monetary policy on inflation observed by Kabundi and Rapapali (2019) in the post-Crisis period. That is, the current study's finding of an increased conduct-related responsiveness to inflation by the SARB post-Crisis coincides with a non-significant transmission-related responsiveness of inflation to the policy rate as reported by Kabundi and Rapapali (2019).

The coefficient on the RER is not significant in either period, which is unsurprising given that South Africa has adopted an explicit inflation targeting framework and not an exchange rate targeting framework, allowing its exchange rate to float relatively freely.

The results for South Africa acquire more meaning when compared to the results of other countries. As such, it is useful to identify a few interesting commonalities – and differences – in the results of the pre- and post-2008 Financial Crisis Taylor Rule regressions among the various countries in the study. The magnitudes and signs of the coefficients in Table 2 differ from country to country, and not all coefficients have the expected signs. This reinforces the notion that aggregated results cannot sufficiently capture the experiences of each country. Thus, an examination of individual central bank results is important for the kind of granular monetary policy analysis that has been the objective of this study.

Markedly, all the developed countries in the sample (US, UK, EU, South Korea and Israel) exhibit structural breaks earlier than the developing countries (South Africa, Brazil, Mexico, Peru, Colombia).[7] This observation speaks to the highly integrated nature of developed countries – spanning finance, banking and trade – while developing countries seem to be relatively less closely integrated into the global financial and economic system. An advantageous consequence of this is that developing countries may have more time to prepare for global shocks.

Moving to the Taylor Rule regressions themselves, it is found that there are only three countries, namely South Africa, Brazil and Mexico, whose smoothing parameters are larger in the post-Crisis

7 Despite there being no statistically significant structural break found for Brazil or Mexico, pre- and post-Crisis regressions for the two countries have nonetheless been included in Appendix 10.5 for the sake of comparison. Ultimately, the somewhat arbitrary structural break date of February 2009 was selected for Brazil and Mexico as this date reflects the timing of a regime switch identified through the Markov-switching regressions and, conveniently, February 2009 also matches the structural break dates of the other two South American countries in the sample, namely Colombia and Peru.

period than in the pre-Crisis period. The other countries display smaller smoothing parameters post-Crisis, with the changes in UK, Colombia and Peru being the most significant according to the Wald test. In particular, the smoothing parameter in the UK falls from 0.955 pre-Crisis to 0.652 post-Crisis, a difference that is statistically significant at the 0.1% level of the Wald test. This illustrates a change in the Bank of England's monetary policy conduct toward being more responsive after the Crisis, so as to close the output and inflation gaps over shorter periods of time. Indeed, the Bank of England is also found to exhibit a more short-run-focused approach, with the long-run response to inflation being negative in both periods, indicating that the Taylor Principle of inflation stabilisation does not hold for the UK. In fact, the UK exhibits a negative coefficient on inflation throughout, against *a priori* expectations – although the coefficient loses significance post-Crisis. The negative sign implies that the Bank of England lowers the policy rate in response to increases in inflation.

Unlike the UK, most countries in the sample exhibit a stabilizing Taylor Rule in both periods pre- and post- the Financial Crisis, as would be expected in countries where monetary policy is guided by the inflation targeting framework. However, there are three countries that experience a switch, namely Peru, South Korea and Brazil. Peru and South Korea have a destabilizing Taylor Rule pre-Crisis and a stabilizing Rule post-Crisis, however the source of the switch is different in each case. For Peru, the smoothing parameter is greater than one pre-Crisis, suggesting that the Central Reserve Bank of Peru was placing too little weight on the current inflation and output gaps to stabilize them in the long run. For South Korea, the negative (but insignificant) inflation coefficient is the source of the destabilization pre-Crisis. Post-Crisis, the coefficient on inflation for South Korea becomes positive but remains insignificant. The third country, Brazil, sees the opposite of Peru, with a smoothing parameter greater than one post-Crisis.

In terms of the changed weightings on inflation and the output gap, the results tend to be specific to each country but there are some common threads. Four out of the ten countries (the UK, Brazil, Mexico and Israel) place a lower weight on inflation post-Crisis, while six place a greater weighting. The change in the inflation coefficient for Israel is not significant according to the Wald test, while the change for the UK is weakly significant at the 10% level. Interestingly, despite showing insufficient evidence of a structural break, Brazil and Mexico also see a statistically significant change in their inflation coefficients pre- and post-Crisis. This suggests that a change in monetary policy conduct can, in certain circumstances, be found to occur, even if there is no clear evidence of a structural break. It is possible that the conduct in Brazil and Mexico changed more gradually over time, and that a methodology such as time-varying parameters may be more suited to capturing this movement. Recall that South Africa is one of the six countries that increased its weighting on inflation after the 2008 Crisis, although the change is not statistically significant. However, the same change

of an increased weighting on inflation is found to be statistically significant for the US, Colombia and Peru, suggesting that their changes in monetary policy conduct may be rooted in this reweighting.

Six central banks reduce their weighting on the output gap after the Crisis, with three (South Africa, the US and the ECB) experiencing statistically significant changes. While this does indicate a change in monetary policy conduct, the decrease in coefficient magnitudes could also have been exacerbated by other factors. Particularly in the developed countries that entered the 2008 Crisis with low interest rates, the zero lower bound problem would have limited central banks' ability to respond to falling output with lower policy rates – hence the smaller coefficient on output post-Crisis. The global economic environment of secular stagnation would also have contributed, as even those countries that saw statistically significant increases in the magnitude of their coefficients on the output gap, namely Peru and South Korea, did not realise their pre-Crisis levels of growth.

The structural break tests, together with the subsequent pre- and post-Crisis regressions, have revealed statistically significant changes in monetary policy conduct for nine out of the ten sample countries. Israel, although having experienced at least one structural break during the 2000 to 2020 period, has not seen a change in monetary policy conduct between the pre- and post-Crisis periods. This reiterates that structural breaks and policy conduct changes are not synonymous.

Table 2: Summary Table of Structural Break Regression Results

*** p<0.01, ** p<0.05, * p<0.1

Country	Variable	Coefficient	Pre-Crisis	Post-Crisis	Wald test significance
South Africa	L1.Policy Rate	φ_1	.9671383***	.9970334***	0.1879
	Inflation	φ_π	.0106729	.0215419***	0.2507
	Output gap	φ_y	.053618***	.014775***	0.0035***
	RER	φ_R	.0004907	.0001348	0.6997
US	L1.Policy Rate	φ_1	.9474221***	.9122644***	0.2691
	Inflation	φ_π	.0025884	.0147883***	0.0721*
	Output gap	φ_y	.0346115**	.0071386**	0.0591*
	RER	φ_R	.0011108	-.0016814	0.1219
UK	L1.Policy Rate	φ_1	.9552287***	.6525278***	0.0000***
	Inflation	φ_π	-.0076069**	-.0013355	0.0995*
	Output gap	φ_y	.0185034*	.009624***	0.2830
	RER	φ_R	.0014463**	.0005963	0.2907
EU (ECB)	L1.Policy Rate	φ_1	.9609398***	.9257484***	0.2875
	Inflation	φ_π	.000164	.0019763	0.6042
	Output gap	φ_y	.0293766**	.0030214	0.0521*
	RER	φ_R	.0000246	-.0009895	0.4769
Brazil	L1.Policy Rate	φ_1	.9793538***	1.015366***	0.1220
	Inflation	φ_π	.0559246***	.019378**	0.0543*
	Output gap	φ_y	.0365384*	.0264829**	0.6525
	RER	φ_R	-.0019518	.0000499	0.2234
Mexico	L1.Policy Rate	φ_1	.9428638***	.9789207***	0.1738
	Inflation	φ_π	.0383046**	.0053877*	0.0710*
	Output gap	φ_y	.0100597	.0152826***	0.7079
	RER	φ_R	.0034225	-.0002246	0.1389
Colombia	L1.Policy Rate	φ_1	.9766548***	.9037843***	0.0105**
	Inflation	φ_π	.0056756	.0255075***	0.0647*
	Output gap	φ_y	.0121006	.0276831**	0.4669
	RER	φ_R	.0005457	-.0002664	0.2894
Peru	L1.Policy Rate	φ_1	1.017516***	.9506393***	0.0053***
	Inflation	φ_π	.0042534	.0200203***	0.0465**
	Output gap	φ_y	-.0012242	.0122898***	0.0007***
	RER	φ_R	.000132	.0018205	0.3737
South Korea	L1.Policy Rate	φ_1	.9717699***	.9478325***	0.2543
	Inflation	φ_π	-.0008648	.0029507	0.1352
	Output gap	φ_y	.0125853***	.0227425***	0.0233**
	RER	φ_R	-.0001847	.0010767***	0.0655*
Israel	L1.Policy Rate	φ_1	.9604163***	.9580104***	0.9125
	Inflation	φ_π	.0125402	.0022845	0.3667
	Output gap	φ_y	.0020595	.0006616	0.7493
	RER	φ_R	-.0066124*	-.0026649**	0.2924

Markov-switching Regressions

Just as a structural break does not necessarily constitute a change in monetary policy conduct, so too does a structural break not necessarily constitute a regime switch. That is, the presence of a structural break does not necessarily imply that a regime change has occurred. The results of the MS regressions allow an assessment of whether or not the identified structural breaks are indeed associated with a change in regime. In addition, this methodology checks the robustness of the structural break dates.

To conduct this analysis, it is useful to make use of a two-state MS regression, allowing the parameters to switch between two states. For each state, the predicted value of the policy rate is obtained, as well as the probability that the state will prevail in each period.

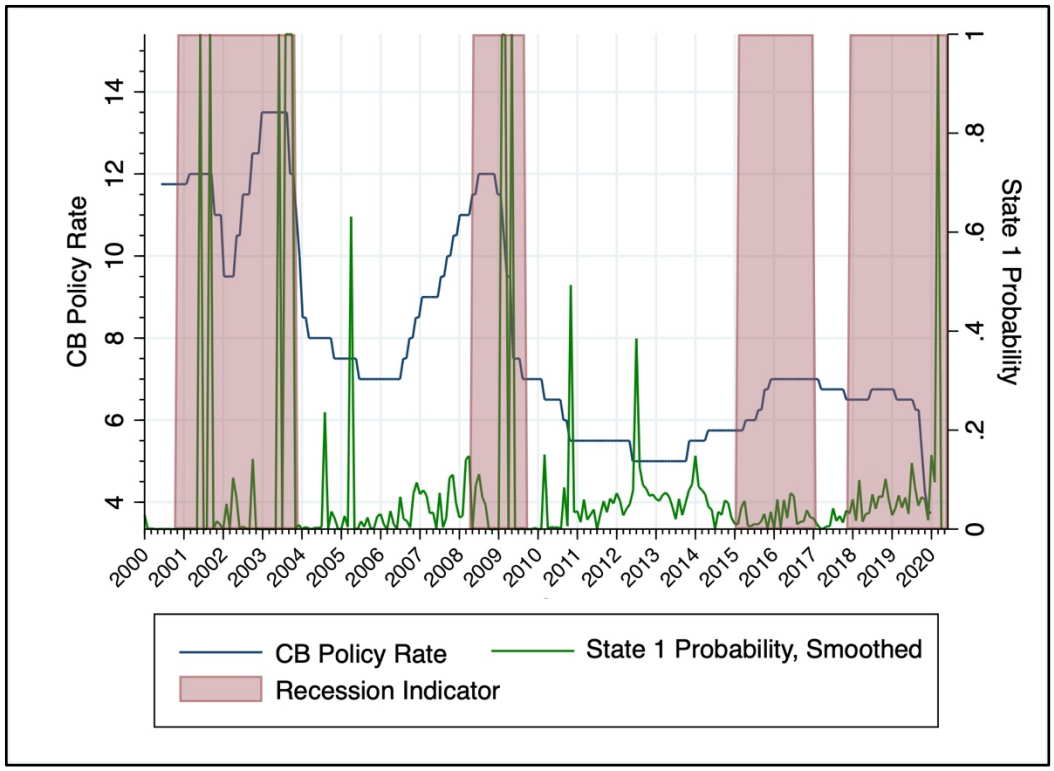
There is evidence of a regime switch when the probability of a given state swings suddenly from being near zero to being near one (and vice-versa). Nine out of the ten countries experience a regime switch during the Financial Crisis, shown by the dramatic swings in state probabilities.[8] The regime switches that occur during the Crisis coincide with the moment of response by central banks, just as was the case in the structural break analysis. This result confirms the robustness of the structural break dates identified in Table 1 above. Table 3 presents a summary of the results of the MS Taylor Rule regressions for all ten countries, for both State 1 and State 2.

South Africa has experienced several regime switches over the sample period, clustered during mid 2001, mid 2003, early 2009 and early 2020. These are all times during which the SARB undertook dramatic policy rate cuts in response to economic downturns. Figure 8 takes a more in-depth look at these switches by showing the actual SARB policy rate and State 1 probabilities together with a recession indicator for South Africa.[9] Figure 9 confirms that a regime switch to State 1 is more likely to occur when the economy is in a recession than when the economy expanding.

Figure 9: OECD-based Recession Indicator for South Africa

8 Only Israel does not appear to experience a regime switch during the Financial Crisis.

9 The OECD-based recession indicator measures a recession as the time between the peak and trough turning points of an economy's growth cycle (Federal Reserve Bank of St Louis, 2020). The indicator is constructed as a dummy variable with a value of one for a recession and zero for an expansion (Federal Reserve Bank of St Louis, 2020). The recession indicator in Figure 3 shows recessionary periods for South Africa, as defined by the OECD.



Data Source: South African Reserve Bank and the St Louis Federal Reserve

The influence of inflation on the policy rate is insignificant during State 1, while the influence of the output gap is highly significant at the 0.1% level in both states. This indicates that emphasis is placed on growth and recovery, highlighting the central bank's focus on steering the economy back on track during a recession. That is, the SARB responds asymmetrically – it reduces the policy rate faster during a recession and increases it more slowly during an expansion. However, between 2015 and 2017, the SARB raised the policy rate during a recession. During this period, the SARB may have acted inappropriately by increasing the policy rate in response to a positive output gap, which, as discussed in Section 5, was likely an artefact of the high average positive output gap brought about by a decrease in potential output after the Crisis.

As seen in Table 3, along with South Africa, seven other countries see a reduction in the size of the smoothing parameter during State 1, six of which are statistically significant according to the Wald test. These decreases in the smoothing parameter reflect the tendency of central banks to be more reactive during a Crisis, in an effort to support and ultimately reignite the economy as quickly as possible. Only the US and Mexico see increases in their smoothing parameters, albeit small and insignificant ones.

The US behaves more inertially during State 1 than State 2. The coefficients on the output gap and inflation for the US drop dramatically in State 1 (though they are insignificant throughout); it seems that the Federal Reserve neglects output and inflation during a recession, in favour of its currency.

The US is not the only country to target its exchange rate in this way – the EU, Peru and Israel also exhibit negative and significant RER coefficients in State 1 – but there are other countries that seem to have the opposite response. Brazil, for example, switches from having a significant negative RER coefficient in State 2, to having a significant positive RER coefficient in State 1 that is double in size. This goes against *a priori* expectations, implying that the Central Bank of Brazil increases the policy rate in response to an appreciation of its currency.

Instead of the RER, the SARB prioritises the output gap and inflation during a recession. The UK, Brazil, Mexico, Peru and South Korea also each have significant output gap coefficients during State 1, the magnitudes of which are all greater than in State 2. The UK, Mexico, Colombia and South Korea complement their response to the output gap with larger and significant weightings on inflation in State 1. It is noted, however, that the output gap coefficients for Mexico and Colombia become negative in State 1, implying that these central banks respond to increases in output by lowering the policy rate. At the same time, Mexico's and Colombia's coefficients on inflation rises considerably, implying that the central bank goes to great lengths to stimulate output while also controlling prices during a recession. The reverse occurs in Peru, with the sign on inflation becoming negative during State 1, and its coefficient on the output gap increases substantially. The sign change on the short-run inflation coefficient leads to the long run response to inflation falling below zero and, as a result, it is possible to conclude that in Peru the Taylor Principle has not been followed during State 1. Accordingly, the Central Reserve Bank of Peru seems to follow a destabilizing Taylor Rule during recessions, prioritising short-run recovery over long term price stabilization.

The expected durations of each state vary across the different countries, along with their transitional probabilities. Similarly, there are mixed results when it comes to how central banks prioritise or even respond to inflation during a crisis. This reinforces the notion that aggregated results cannot sufficiently capture the experiences of each country and that a granular examination of individual central bank results is important for accurate monetary policy analysis.

Table 3: Summary Table of Markov-switching Regression Results
*** p<0.01, ** p<0.05, * p<0.1

Country	Variable	Coefficient	State 1	State 2	Wald test significance
South Africa	L1.Policy Rate	γ_{1,S_t}	.9066523***	1.004197***	0.0272**
	Inflation	γ_{π,S_t}	.0343435	.0119154***	0.3636
	Output gap	γ_{y,S_t}	.0891239***	.0166032***	0.0098***
	RER	γ_{R,S_t}	.0019279	-.0001591	0.5211
US	L1.Policy Rate	γ_{1,S_t}	1.023986***	1.013094***	0.6574
	Inflation	γ_{π,S_t}	-.0009	.002185	0.6632
	Output gap	γ_{y,S_t}	.0004182	.0010996	0.9274
	RER	γ_{R,S_t}	-.0053736***	-.0003538	0.0006***
UK	L1.Policy Rate	γ_{1,S_t}	.8029554***	.9982149***	0.0000***
	Inflation	γ_{π,S_t}	-.0657388***	-.0044156**	0.0000***
	Output gap	γ_{y,S_t}	.0699562***	.0035137**	0.0039***
	RER	γ_{R,S_t}	.0121048***	.0005337**	0.0000***
EU (ECB)	L1.Policy Rate	γ_{1,S_t}	.9109344***	1.007502***	0.0139**
	Inflation	γ_{π,S_t}	.0059949	-4.51e-06	0.6823
	Output gap	γ_{y,S_t}	-.0199777	.0025949	0.4058
	RER	γ_{R,S_t}	-.0025451***	-6.79e-06	0.0101**
Brazil	L1.Policy Rate	γ_{1,S_t}	.9203594***	1.016016***	0.0000***
	Inflation	γ_{π,S_t}	-.0302629**	.0431871***	0.0000***
	Output gap	γ_{y,S_t}	.1015134***	.0135178	0.0000***
	RER	γ_{R,S_t}	.0041849***	-.0021629**	0.0004***
Mexico	L1.Policy Rate	γ_{1,S_t}	1.020309***	1.0201**	0.9948
	Inflation	γ_{π,S_t}	.1105393***	.0094456*	0.0000***
	Output gap	γ_{y,S_t}	-.116538***	.0076263	0.0000***
	RER	γ_{R,S_t}	.0013007	.000212	0.7812
Colombia	L1.Policy Rate	γ_{1,S_t}	.9176357***	.9866532***	0.0000***
	Inflation	γ_{π,S_t}	.0190047**	.0064159	0.3108
	Output gap	γ_{y,S_t}	-.0575296**	.0104878	0.0466**
	RER	γ_{R,S_t}	.0001375	-.0000565	0.8399
Peru	L1.Policy Rate	γ_{1,S_t}	.9359181***	.9921834***	0.0261**
	Inflation	γ_{π,S_t}	-.0063033**	.0069986**	0.0017***
	Output gap	γ_{y,S_t}	.0065842**	.0000125	0.0339**
	RER	γ_{R,S_t}	-.0027774*	.0002445	0.0742*
South Korea	L1.Policy Rate	γ_{1,S_t}	.9729864***	1.005276***	0.1063
	Inflation	γ_{π,S_t}	.0195481***	-.0004797	0.0001***
	Output gap	γ_{y,S_t}	.0276135***	.0067261***	0.0000***
	RER	γ_{R,S_t}	.0012062	.000497**	0.6237
Israel	L1.Policy Rate	γ_{1,S_t}	.9751117***	1.004035***	0.6772
	Inflation	γ_{π,S_t}	.0038049	.1283229***	0.0000***
	Output gap	γ_{y,S_t}	.0007566	.1073845***	0.0000***
	RER	γ_{R,S_t}	-.0024483***	-.0518848***	0.0000***

Conclusions

Through a combination of structural break tests and Markov-switching Regressions, the study presents evidence of Crisis-related changes in monetary policy conduct in South Africa, as well as in the US, the UK, the Euro Area (the ECB), Colombia, Peru and South Korea. On the other hand, the results for Brazil, Mexico and Israel do not show conclusive differences in monetary policy conduct between the pre-Crisis and post-Crisis periods. Moreover, the Markov-switching regressions with two-states reveal that central bank conduct could be further dissected into that undertaken before, during and after a crisis or, alternatively, that undertaken during a recession and during an expansion.

As hypothesised, the 2008 Crisis resulted in changes in the coefficients or weightings within the Taylor Rules for each country. While the change in monetary conduct in each country is quite unique, there are some common threads and interesting differences. Along with South Africa, there are only two other countries, namely Brazil and Mexico, whose smoothing parameters are larger in the post-Crisis period. The other sample countries display smaller smoothing parameters post-Crisis, with the change in UK being the most significant.

The UK also exhibits a destabilizing Taylor Rule, with a negative long-run coefficient on inflation throughout the 20-year time frame. This is in contrast to Peru, which has a negative long-run coefficient on inflation pre-Crisis but a positive one post-Crisis. Unlike the UK and Peru, most countries in the sample exhibit a stabilizing Taylor Rule both pre- and post- the Financial Crisis, as would be expected in countries where monetary policy is guided by the inflation targeting framework. Four out of the ten countries place a lower weight on inflation post-Crisis, while six place a greater weighting. Six central banks reduce their weighting on the output gap after the Crisis.

The real exchange rate does seem to play a significant role in the decisions made by central banks during a crisis, or recession. The Markov-switching regressions reveal that the US, EU Area (under the European Central Bank), Peru and Israel targeted changes in their exchange rates during the 2008 Crisis, likely in an effort to maintain trade competitiveness and boost local output through this channel.

References

Ball, L., 2000. *Policy Rules and External Shocks*. [Online] Available at: https://www.nber.org/papers/w7910.pdf [Accessed 22 July 2020].

Baxa, J., et.al., 2010. *How Does Monetary Policy Change? Evidence on Inflation Targeting Countries.* [Online] Available at: https://ideas.repec.org/p/fau/wpaper/wp2010_26.html [Accessed 9 July 2020].

Boivin, J., 2005. *Has US Monetary Policy Changed? Evidence from Drifting Coefficients and Real-Time Data.* [Online] Available at: https://www.nber.org/papers/w11314.pdf [Accessed 8 July 2020].

Brown, R., Durbin, J., & Evans, J., 1975. Techniques for Testing the Constancy of Regression Relationships over Time. *Journal of the Royal Statistical Society. Series B (Methodological)*, Volume 37(2), 149-192.

Chow, G., 1960. Tests of Equality Between Sets of Coefficients in Two Linear Regressions. *Econometrica*, Volume 28(3), pp. 591-605.

Clarida, R., Gali, J. & Gertler, M., 2000. Monetary Policy Rules And Macroeconomic Stability: Evidence And Some Theory. *Quarterly Journal of Economics*, Volume 115(1), pp. 147-180.

Coco, A. & Viegi, N., 2020. *The monetary policy of the South African Reserve Bank: stance, communication and credibility*. [Online] Available at: https://www.resbank.co.za/en/home/publications/publication-detail-pages/working-papers/2020/10024 [Accessed 10 June 2021].

Creel, J. & Hubert, P., 2010. *Has Inflation Targeting Changed the Conduct of Monetary Policy?*. [Online] Available at: https://www.researchgate.net/publication/228538284_Has_Inflation_Targeting_Changed_the_Conduct_of_Monetary_Policy [Accessed 8 July 2020].

Debelle, G., et. al., 1998. *Inflation Targeting as a Framework for Monetary Policy*.[Online] Available at: https://www.imf.org/external/pubs/ft/issues/issues15/ [Accessed 13 January 2021].

de Medeiros, G. B., et. al., 2016. Robust monetary policy, structural breaks, and nonlinearities in the reaction function of the Central Bank of Brazil. *EconomiA*, Volume 17, pp. 96-113.

De Nicolò, G., Favara, G., & Ratnovski, L., 2012. *Externalities and Macroprudential Policy.* [Online] Available at: https://www.imf.org/external/pubs/ft/sdn/2012/sdn1205.pdf [Accessed 11 January 2021].

Drakos, A. & Kouretas, G., 2015. The conduct of monetary policy in the Eurozone before and after the financial crisis. *Economic Modelling,* Volume 48, pp. 83-92.

Federal Reserve Bank of St. Louis, 2020. *Federal Reserve Bank of St. Louis' Financial Crisis Timeline*. [Online] Available at: https://fraser.stlouisfed.org/timeline/financial-crisis [Accessed 14 July 2020].

Frappa, S. & Mésonnier, J., 2009. *The Housing Price Boom of the Late '90s: Did Inflation Targeting Matter?*. [Online] Available at: https://publications.banque-france.fr/sites/default/files/medias/documents/working-paper_255_2009.pdf [Accessed 28 August 2020].

Greenspan, A., 2004. Risk and Uncertainty in Monetary Policy. *American Economic Review*, (94)2, pp. 33-40.

Jahan, S., 2017. Inflation Targeting: Holding the Line. [Online] Available at: https://www.imf.org/external/pubs/ft/fandd/basics/target.htm [Accessed 14 July 2020].

Kabundi, A. & Rapapali, M., 2019. The transmission of monetary policy in South Africa before and after the global financial crisis. *South African Journal of Economics*, Volume 87(4), pp. 464-489.

Mishkin, F., 2011. *Monetary Policy Strategy: Lessons from the Crisis.* [Online] Available at: https://www.nber.org/papers/w16755 [Accessed 6 July 2020].

Murray, C., Nikolsko-Rzhevskyy, A., & Papell, D. (2015). Markov Switching and the Taylor Principle. *Macroeconomic Dynamics*, 19(4), 913-930.

Perruchoud, A., 2009. Estimating a Taylor Rule with Markov Switching Regimes for Switzerland. *Swiss Journal of Economics and Statistics*, Volume 145, pp. 187-220.

Strohecker, K., 2020. *Analysis: Thumbs up for emerging markets' QE experiment but risks loom*. [Online] Available at: https://www.reuters.com/article/emerging-markets-qe-yearend-analysis-int/analysis-thumbs-up-for-emerging-markets-qe-experiment-but-risks-loom-idUSKBN2930FW [Accessed 11 January 2021].

Taylor, J. B., 1993. Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy,* Volume 39, pp. 195-214.

Taylor, J. B., 1998. *An Historical Analysis of Monetary Policy Rules.* [Online] Available at: https://www.nber.org/papers/w6768.pdf [Accessed 14 July 2020].

Taylor, J.B., 2009. The Need to Return to a Monetary Framework. *Business Economics*, Volume 44(2), pp. 63-72.

Woglom, G., 2003. How has inflation targeting affected monetary policy in South Africa? *South African Journal of Economics*, Volume 71(2), pp. 198-210.