Spillovers of the Conventional and Unconventional Monetary Policy from the US to South Africa

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Abstract

This paper assesses the effect of US monetary policy on South Africa during the period 1990- 2018. We separately analyse and compare the effect of conventional monetary policy, before the Global Financial Crisis, and unconventional monetary policy, after the US monetary policy reached the zero-lower bound. Our impulse response function results indicate that monetary policy in South Africa is somewhat independent, responding to local inflation, economic activity and financial conditions. However, the variance decomposition also indicates that the US monetary policy accounts for some variation of the South African policy rate. Finally, we find a sluggish response of industrial production and credit differ post the global financial crisis. We see this as an indication of the effects of structural issues to the real economy, political uncertainty and constrained households' balance sheet which has prevented the local economy to take advantage of low local interest rates and the global economic recovery after the crisis.

JEL Codes: E52, F36

Keywords: International spillovers, unconventional monetary policy, zero-lower bound, South Africa

1 Introduction

A country's integration in the global financial system raises the question of what are the exchange rate regime, the monetary policy framework and the financial stability regulation that guarantee the benefit of financial integration while allowing a significant degree of independence in local policy making. The choice in South Africa, and in many emerging countries, has been to rely on a combination of flexible exchange rate, inflation targeting and free capital mobility. This is in accordance with the Mundellian trilemma hypothesis Obstfeld et al. (2005) by which an independent monetary policy is compatible with free international capital mobility only at the cost of letting the exchange rate be determined by market forces. This has been the consensus in international economics for decades and it justifies the policy framework chosen in many emerging countries. The financial crisis has raised questions over the validity of this consensus view. Rey (2016) at the Jackson Hole meeting of 2013 famously raised the

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possibility that global financial flows are transmitting the United States monetary policy to the rest of the world. Rey (2015, 2016) argue that because the US dollar plays a central role in international transactions, US monetary policy is transmitted to other countries through an international credit and/or risk-taking channel. This transmission generates a strong co-movement in risky assets across the globe thus generating a global financial cycle. The transmission of the global financial cycle to local economies compels monetary policy in each country to react to prevent local financial instability instead than focusing on its main macroeconomic objective. Any country faces a dilemma: either allow free movement of capital, and loose monetary independence, or introduce capital controls or macro-prudential tools to gain renew control on the instruments and goals of monetary policy. These results are striking and have strong implications for policy making in emerging countries.

This paper examines empirically the applicability of Rey (2016)'s findings to South Africa. South Africa is an ideal candidate to test the dilemma hypothesis because it has the most developed and integrated financial market of any emerging country, with large equity and bond markets, see Kavli and Viegi (2017). On the other hand its banking system is dominated by a few local banks, financed by local sources, and thus less affected by resource allocation of global banks Bruno and Shin (2013). First we analyse the co-movement between global and local risky financial assets. We investigate this hypothesis by extracting the South Africa financial cycle from a panel of financial variables, using the dynamic factor model. We then analyse the correlation of this South Africa financial cycle with both the global cycle and global financial risk. As suggested by Rey (2015, 2016) and Bruno and Shin (2015), the presence of a high correlation between local and global financial cycles is the first indication of a possible dependency of South Africa monetary policy to the Reserve policy.

The correlation of financial cycles is a necessary but not sufficient condition for dependence. The other condition is that the financial cycle affect directly or indirectly the setting of monetary policy in the periphery. To assess the channels of transmission of the US monetary policy to South Africa, we use a medium Bayesian vector autoregressive (BVAR) model with Minnesota priors, proposed by Bańbura et al. (2010) covering the period January 1990 to February 2018. We identify US monetary policy shocks and we then determine its' spillovers to South Africa. We conduct the analysis by dividing the sample into two sub-samples, before and after 2008, to account for the dramatic change in US monetary policy after the global financial crisis, once the Fed funds rate reached the zero lower bound and the Federal Reserve started its policy large-scale asset purchases (LSAPs).

Our results indicate that the global financial cycle affects the valuation of risky assets, as predicted by Rey (2015), but assets prices changes are not transmitted to the real economy because of a muted credit response. The exchange rate channel is the dominant one and monetary policy responds mainly to local inflation and economic activity.

Before and after the financial crisis, an expansionary US monetary policy reduces global risk, increases purchase of stocks by non-residents and leads to an appreciation of the South African currency against the US dollar. While before the crisis a US monetary policy expansion had a positive effect on South Africa real economy by expanding global demand, after the crisis we see a US monetary expansion had a contractionary effect on industrial production and credit. These results highlight local structural issues in the real sector and constrained households' balance sheets post the global financial crisis.

The rest of the paper is organised as follows: after the literature review in the next section, we present the analysis of the correlation of South African and global financial cycles, which become highly correlated after the global financial crisis. In Section 4 instead we briefly describe the methodology and the data used in the VAR analysis. The results for the VAR analysis are then presented in Section 5. Finally Section 6 concludes.

2 Global transmission of US monetary policy

The importance of the financial channel in the global transmission of shocks has been the subject of a large international finance literature, starting from the classical Mundell (1960) on the assignment of instrument to target in open economy. The central question of this literature has been the constraints imposed on national policy making by a country's integration into the international financial system. After the global financial crisis the question has found new answers that have generated a wide debate. Rey (2015) main argument is that global financial flows act as a transmission of US monetary policy across the globe and that the exchange rate regime is largely irrelevant in insulating national economies from these shocks. This observation generalizes to the global economic considerations that were previously largely limited to emerging countries policy experience by Calvo (1998); Calvo and Reinhart (2002). Similarly, Obstfeld (2019) elaborates how the US dollar's global role explains why the US unconventional monetary policy had far-reaching effects to both emerging and developed markets than other developed economies' unconventional monetary policies. These roles include US dollar as a reserve, trading "vehicle", invoicing and funding currencies. According to the author, it is the latter two that matter more in the transmission of US monetary policy to other countries via the international trade and global finance respectively.

Because the US dollar is the currency of global finance, a change in US monetary policy changes the cost of funding for global banks, Adrian and Shin (2009), the prices of dollar assets in the US and abroad, and the allocation of capital and credit conditions across the world, Giovanni et al. (2017). International capital flows are procyclical and potentially destabilizing for the receiving country: a US monetary expansion increases asset values, reduces the cost of funds and increases the risk appetite of global banks and global financial intermediaries, Borio and Zhu (2012); Bruno and Shin (2013). This increases international capital flows, increasing asset prices and credit provision across the globe; the revaluation of local currencies relative to the US reinforces the mechanism by making local assets more valuable in US dollar terms; this generates a local assets and credit boom that local monetary policy has little instruments to fight, as argued by Rey (2016). In this scenario, a flexible exchange rate is irrelevant, if not damaging, in insulating the country from global shocks. The only instrument available is some kind of capital controls or macroprudential policy to slow down the procyclical effect of capital flows [1]. The normative effect of the analysis is striking: either a country accepts that the benefits of international capital flows come with potential destabilizing effects and a loss of monetary sovereignty, or it has to impose capital control, or credit control or manage the financial system to regain monetary independence. This is the "dilemma" facing the policy maker according to Rey (2015).

The debate that has followed Rey (2015)'s contribution is large and continuously developing and this paper is just another contribution from the point of view of a significant (financially) emerging country. Obstfeld (2015) and Obstfeld et al. (2019) argue that emerging countries with a flexible exchange rate are better positioned to "weather the storm" capital flows shocks. On the other hand they also recognise that financial globalization does create difficulties for national economic management but doubtful that capital control can play a role. The Mundellian trillemma is then still applicable, tough in an amended form. Bernanke (2017) instead points out that the existence of the co-movement of financial assets does not invalidate the trilemma hypothesis. Firstly, asset prices (and monetary policies across the globe) can co-move in response to a global common shock. In addition, he argues that emerging markets forgo their monetary policy independence voluntarily by pursuing trade competitiveness in addition to their

[1] See Ostry et al. (2012) for a review of the instruments available to manage capital flows and Chamon and Garcia (2016) for an analysis of capital control measures implemented in Brazil in the years after the Global Financial Crisis

domestic objectives. This then results in a zero-sum game as any policy rate reaction to fight local currency volatility can be at odds with their objectives of output stability. Therefore, the problem is not the US policy spillovers, but rather that emerging markets try to use a single instrument (the policy rate) to achieve both output and financial stability objectives.

The empirical evidence is, as expected, mixed: for developed countries, results by Rey (2015, 2016), Bruno and Shin (2015), Miranda-Agrippino and Rey (2018) and Gerko and Rey (2017) show that US monetary policy affect both monetary policy and financial variables in major economies and financial centres like UK, Canada, New Zealand and the Euro area. Similarly, for emerging markets, Hofmann and Takats (2015) find that domestic macroeconomic variables and global risk (proxied by the VIX) significantly affect both interest rates and policy rates and that exchange rate flexibility does not enhance monetary policy independence.

Obstfeld et al. (2019) investigate the relevance of the exchange rate regime for financially integrated emerging economies between 1986 and 2013 using panel data analysis. The authors find that domestic financial conditions (with exception to asset prices) respond more to the global financial conditions in a fixed exchange rate regime than they do in a floating exchange rate regime. Even though these results are supportive of the insulation of flexible exchange rate, the authors find that there is no statistical difference between intermediate (managed) exchange rate regimes and the free-floating regimes. This according to the authors, implies that countries do not have to have a completely free-floating exchange rate to enjoy the benefits of a flexible exchange regime.

The research on monetary spillovers to South Africa is quite limited. Kavli and Viegi (2017) analyse the determinants of capital flows in South Africa and in particular the importance of global risk factors, in line with Rey (2015) argument. Using a time varying framework, they show that the strong correlation between global risk factors and capital flows in South Africa is evident only around the global financial crisis and almost exclusively in the bond market. This would suggest a loss of monetary independence only if bond flows induce changes in local credit and financial conditions. Algu and Creamer (2017) evaluate directly the existence of monetary policy trilemma and dilemma in South Africa during the period 1970Q1 and 2012Q4. They perform a linear regression of the macroeconomic trilemma indices - monetary policy independence, exchange rate stability, and capital flow index and they also use a three-variable vector autoregressive model which includes inflows, exchange rate and the 3 months Treasury bills. Overall, they find their results supportive of monetary policy independence in South Africa.

Results on South Africa can also be found in a few international studies, such as Hofmann and Takats (2015), Anaya et al. (2017), and Obstfeld et al. (2005) among others. Bowman et al. (2015) and Anaya et al. (2017) analyse the effects of US unconventional monetary policy on emerging markets. Bowman et al. (2015) estimate both a panel and country-specific impulse response functions using daily data. The results for the impulse response function for South Africa (and most of the other emerging countries) are mostly insignificant. However, average results indicate that sovereign risk respond significantly whereas exchange rate and stock prices are insignificant. Anaya et al. (2017) use a structural global VAR for the period January 2008 to December 2014 using monthly data. The results are mainly consistent with the literature - an expansionary policy stance in the US causes inflows to emerging countries which results in local currency appreciations and increase in asset prices. Unlike the authors, we specifically control for inflation since South Africa is an inflation-targeting country.

Our study on policy spillovers to South Africa add to these studies in several ways: firstly, we expand on Kavli and Viegi (2017) by showing the relationship between international capital flows and internal economic conditions. While US monetary policy affects local asset prices, it does not significantly influence credit conditions to neutralize the traditional exchange rate channel. Secondly, by using a medium scale BVAR, we are able to overcome some of the limitations of Algu and Creamer (2017) who use a small VAR are not able to include in the analysis both US and South African variables, to study the monetary policy spillover from the US to South Africa. This is because large Bayesian VAR methodology of Bańbura et al. (2010) enables us to include a large number of variables without losing degrees of freedom. We are than able to overcome the problem of omitted variable bias which might be present in Algu and Creamer (2017). We are also able to compare our results to the international literature - Rey (2016), Bruno and Shin (2015), Miranda-Agrippino and Rey (2018) and Gerko and Rey (2017). Finally, we separate our analysis for before and after the 2008 crisis. We can test if there has been a significant structural change in the transmission of conventional vs unconventional monetary policy as suggested by Kavli and Viegi (2017) and argued by Bruno and Shin (2015) or if the relationship is stable, as discussed in Miranda-Agrippino and Rey (2018).

3 The South African and Global Financial cycles

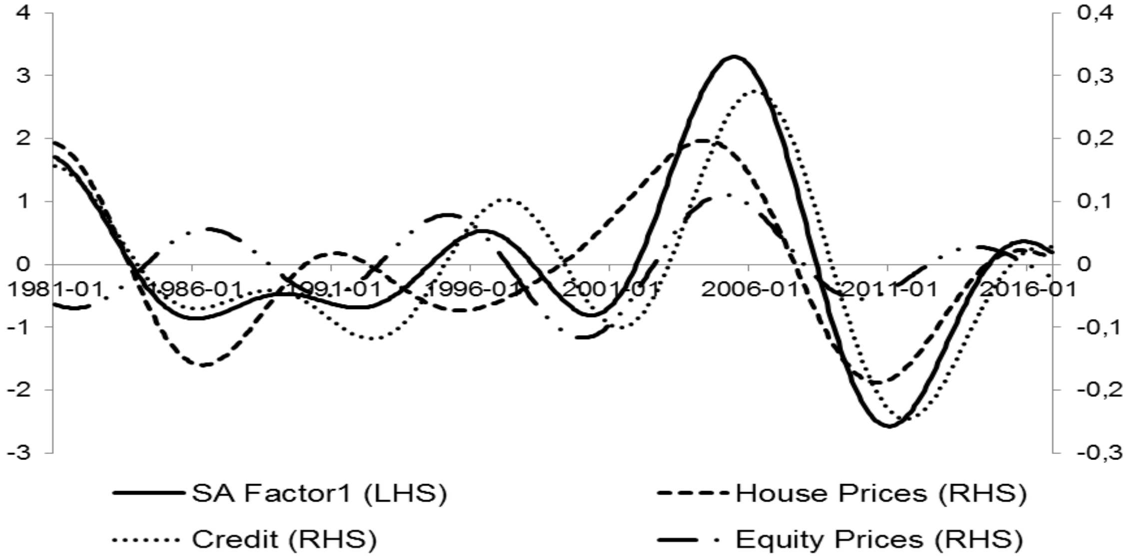
The financial cycle captures swings in perceptions and attitudes about financial risk which are reflected in the associated co-movement of global financial developments (Ng (2011)). The literature on the international credit channel or the risk-taking channel postulate that these changes in perceptions and attitudes by investors are influenced by monetary policy in the US, among other things.

The question we ask in this section is how integrated is the South African financial cycle to the rest of the world. To answer this question, we analyse the relationship between the local and the global financial cycle. To do this, we construct a measure of the local financial cycle using factor analysis for the period January 1981 to November 2016. Similar to the South African Reserve Bank (SARB), we use three variables to construct the cycle: domestic house and stock prices and credit growth. We follow the Bank's methodology. First, we deflate the data using the consumer price index, then we take the first difference of the variables in logs and finally normalise the data. After this data transformation, we use the Christiano and Fitzgerald (2003) band pass filter with the financial cycle frequency band of 8 to 30 years (96 to 360 months with our monthly frequency) to extract the cyclical components of the three variables. And lastly, we extract the common factor between the cyclical components to get our first measure.[2] In the end the common factor of the financial cycle explains 61% of the variance in the variables.[3] Figure 1 shows the computed measure of the financial cycle for South Africa and its three components. The figure shows that there are three downturns during the sample period of January 1981 to November 2016. The first downturn is between first quarter of 1984 and third quarter of 1994. This downturn is consistent with the period of political instability during the Apartheid regime and the 1985 South African debt or financial crisis. A comparison with its components suggest that credit growth is the main driver of the persistence of the downturn, making it the longest during the sample period. The figure also suggest that house prices leads the cycle whereas credit growth lags it. The second downturn is between the period 1998 and 2002, which coincides with the Asian and technology crises. The last downturn is during the 2008 global financial crisis and lasts for almost 7 years.

[2]We use the Alessi et al. (2008) criterion to determine the number of common static factors driving the data. This is a modified Bai and Ng (2002) estimator. The idiosyncratic components are allowed to be autocorrelated.

[3]We also explored a second measure similar to that of Domanski et al. (2011) and Hatzius et al. (2010), depending on the availability of data. The available data starts from December 1986. Here we extend the three variables in the first measure with commodity prices, real effective exchange rate, monetary policy aggregates (M1, M2 and M3), a measure of risk (spread of 10 year bonds and Eskom bond) and spread between short to medium term rates and medium to long-term rates. In this case the common factor explain 28% of the variance of the variables. Excluding the spreads and commodity prices increases the variance from 28% to 45%.

Figure 1: South African financial cycle

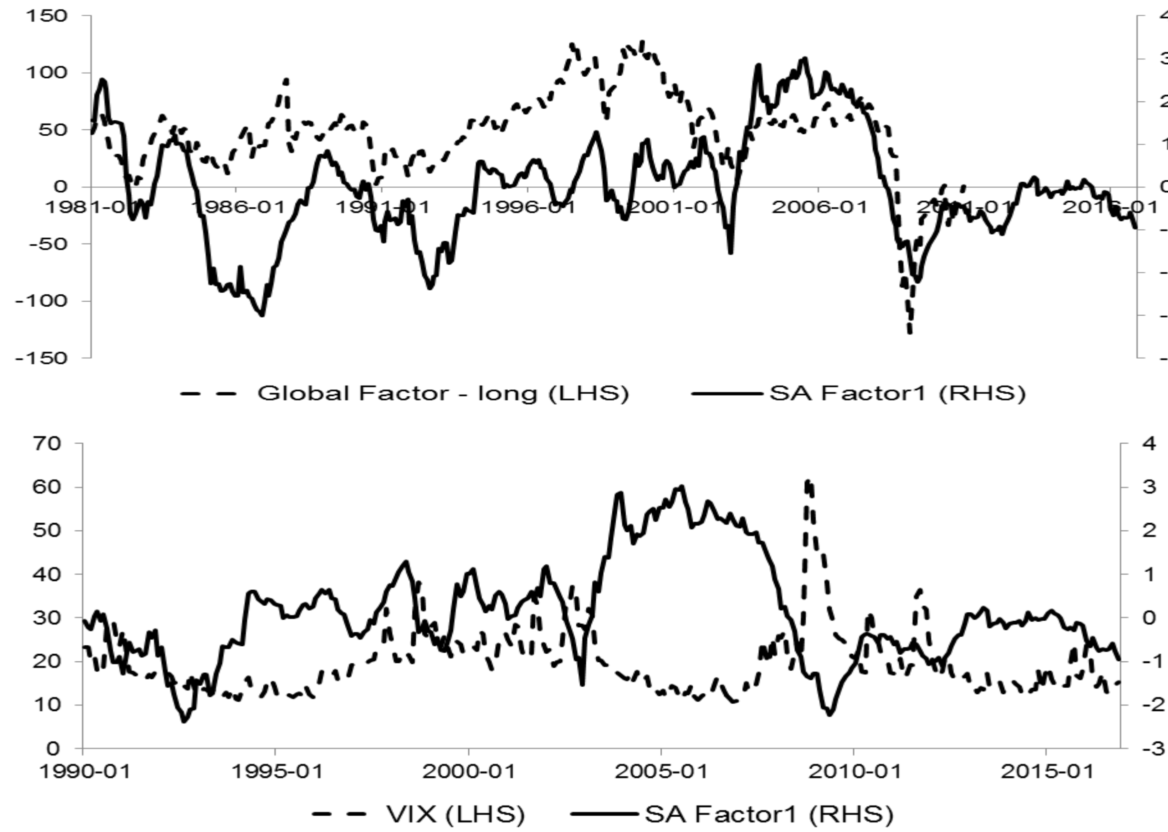


Note: The figure shows the computed financial cycle for South Africa on the left hand scale and its components on the right hand scale. The components are: Absa House price index, Johannesburg All Share Prices and Total Credit to the private sector. The three variables are firstly deflated using the consumer price index, then first log differences and lastly normalised. All data is in monthly for the period January 1981 to November 2016.

In Figure 2, we compare the local financial cycle to the measures of the global financial cycle and risk. We use the global factor by Miranda-Agrippino and Rey (2018) for the global financial cycle and the widely used VIX index for global risk. The starting dates for the global factor and the VIX dictate the starting dates of our comparison. We use the three-variable measure of local financial cycle, which is the unfiltered version of Figure 1. Starting with the comparison with the global factor, the figure shows that there is a co-movement between the local cycle and the global cycle, especially from 2002 onwards, as South African became a more open economy. Pre-2002, the relationship is sometimes not that obvious and in some cases suggests that the local cycle is lagging the global cycle. The comparison with the VIX in the bottom panel shows that the local cycle has a negative relationship with global risk. Therefore, there is strong evidence that increase in global risk reduces financial conditions in South Africa.

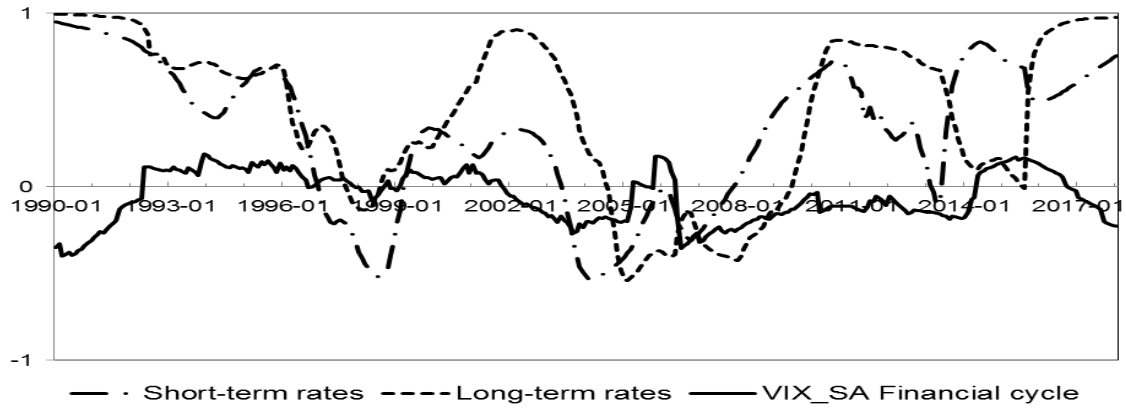
Lastly, Figure 3 shows a 5-year moving correlation between the short-term rates and the long-term rates for the US and South Africa, and the VIX and the South African financial cycle. There's a positive, and sometimes high, correlation between the rates along the yield curve. Even though long-term rates are market-driven, the correlations between the short and long-term rates co-move together, with exception of the period between June 2013 and February 2016, where the two correlations are negatively co-moving. Unlike for the rates, the negative correlation between the VIX and the South African financial cycle is small.

Figure 2: Global and Local Factors



Note: The figure compares the local financial cycle to the measures of global financial cycle and global risk. In the top panel the global factor by Miranda-Agrippino and Rey (2018) is used as a proxy for the global financial cycle. In the bottom panel the CBOE VIX is used as a proxy for global risk.

Figure 3: Correlation - 5 year window



Note: The figure shows a 5 year moving average between the South African and US variables. Short-term rates are proxied by Federal Reserve Fund rate and the South African repo rate. Long-term rates are proxied by monthly yield on loan stock traded on the stock exchange: government bonds - 10 years and over and market yield on U.S. Treasury securities at 10-year constant maturity quoted on investment basis. VIX as the CBOE volatility index and the local financial cycle.

4 VAR analysis and Data

Similar to Rey (2016) and Miranda-Agrippino and Rey (2018), we analyse monetary policy spillovers from the US to South Africa using a medium scale Bayesian VAR model. As discussed in Bańbura et al. (2010), large Bayesian VAR analysis overcomes the size limitation problem of variables which is common in regression analysis and particularly the VAR analysis. This then allows the inclusion of more variables - disaggregated, sectoral and geographical data in the information set. Therefore, Bayesian VAR is an alternative to factor models and panel VARs. Since we want to include both US and South African variables, we apply this methodology. See Appendix 4 for model details.

We use monthly data from January 1990 to February 2018 and divide our sample into two sub-samples - the pre zero-lower bound period of 1990 to 2008 and the post zero-lower bound period of 2008 to 2018. These pre- and post-ZLB sub-samples allow us to look at the effects of conventional and unconventional US monetary policy spillover on the local economy. Our model include real and nominal variables for the US and South Africa, monetary policy instruments in the two countries and financial variables for the two countries.

In both periods, the model consists of 20 variables. As is standard in the medium to large Bayesian VAR literature, we order the slow moving variables first followed by the fast moving variables last. We assume the following ordering structure, $Y_t = (X_t^{us}, X_t^{sa}, r_t^{us}, Z_t^{us}, r_t^{sa}, Z_t^{sa})'$, where X_t^{us} and X_t^{sa} represent the slow moving variables for the US and South Africa respectively, r_t^{us} is the monetary policy in the US, Z_t^{us} represents the fast moving variables in the US, r_t^{sa} is the monetary policy in South Africa and lastly Z_t^{sa} is the fast moving variables in South Africa. With this ordering structure, we assume that the slow moving variables in both the US and South Africa do not respond contemporaneously to US monetary policy. In addition, we assume that the fast moving variables respond contemporaneously to everything. We treat the South African monetary policy as a fast moving variable, but order it first to the fast moving South African variables. This ordering allows us to maintain the ordering of slow and fast moving variables within the South African block as $Y_t^{sa} = X_t^{sa}, r_t^{sa}, Z_t^{sa}$. That is, within the local economy, monetary policy authorities can only respond with a lag to slow moving variables.

The structural VAR can be represented as:

$$A_0 Y_t = c + A_1 Y_{t-1} ... + A_p Y_{t-p} + \eta_t \tag{1}$$

where Y_t is the N vector of endogenous variables, A_0 is the $N \times N$ contemporaneous impact matrix, c is a N vector of coefficients and η_t is the $N \times N$ error matrix. The reduced form equation can be written as:

$$Y_t = B_0 + B_1 Y_{t-1} ... + B_p Y_{t-p} + \varepsilon_t \tag{2}$$

where $B_0 = A_0^{-1} c$, $B_i = A_0^{-1} A_i$ for $i = 1, ..., p$ and $\varepsilon_t = A_0^{-1} \eta_t$. And the variance covariance matrix of the reduced form VAR is given by:

$$E(\varepsilon_t \varepsilon_t') = E(A_0^{-1} A_0^{-1\prime}) = \Sigma \tag{3}$$

4.1 Identification of monetary policy in the US

For the sub-sample January 1990 to December 2008, the period of conventional monetary policy, we use the Federal Fund rate as our monetary policy instrument. Therefore, monetary policy is identified as an exogenous innovation to the Federal Fund rate. We impose zero restrictions on the contemporaneous impact matrix A_0. Using the lower triangular Cholesky decomposition of the reduced form covariance-variance matrix Σ, we can identify the structural shocks. Given the ordering of our variables, this means that we assume that real or slow moving variables in the US do not contemporaneously respond to the US monetary policy. The Federal Fund rate respond contemporaneously only to the real variables in the US. This identification is consistent with Bańbura et al. (2010). Given our interest in the risk-taking channel, correct identification should also show an increase (decrease) in global risk following a contractionary (expansionary) US monetary policy.

For the post-ZLB period, January 2009 to February 2018, we follow Boeckx et al. (2017) and Gambacorta et al. (2014) and use total assets of the Federal Reserve Bank as our monetary policy instrument. In this case, a one-standard deviation of the total assets shock proxies the effects of the large-scale asset purchases (LSAPs) policies by the Fed. Several studies have looked at the effects of such unconventional monetary policy actions (Boeckx et al. (2017), Gambacorta et al. (2014) and Swanson (2017) among others). Using a cross-country analysis, Gambacorta et al. (2014) find that for countries that increased their central banks' balance sheets (US, UK, Canada and Euro area), both prices and output increased. Boeckx et al. (2017) find similar results for the European area. However, the authors find that the effects of unconventional monetary policy actions are short-lived, only lasting for 2 - 3 months.

Unlike Boeckx et al. (2017) and Gambacorta et al. (2014), we only use zero restrictions, instead of a combination of zero and sign restrictions, to identify monetary policy. This allows us to be able to compare the results for the two periods.

4.2 Data

We use monthly data for the US and South Africa for the period January 1990 to February 2018. The US variables are obtained from the Federal Reserve Bank and Federal Reserve Bank of St. Louis whereas the South African data is from the South African Reserve Bank. Table 6 provides the ordering, source, transformation and random walk prior assumptions of the variables. Following the medium scale BVAR model for the US by Bańbura et al. (2010), we include the following variables for the US in our analysis: employment, industrial production, the Fed rate, inflation, effective exchange rates, yields on 10 year bond, Standard Poor's stock price index as proxy for stock prices, commodity prices, total reserves and M1 money stock. Similarly, we include the following variables for South Africa: nominal exchange rates, yield on 10 year bond, house price index[4], Johannesburg stock price index as proxy for stock prices. Since our goal is to analyse the risk-taking channel or credit channel, we add credit extended to the private sector for South Africa and the VIX index as a measure of global risk. Lastly, we also include the net purchase of shares by non-residents (as a share of total sales and purchases of shares by non-residents). All nominal values are deflated using the price deflators.[5]

[4]Due to the discontinuation of the ABSA house price index from November 2016, we use the FNB house price index for crisis and post-crisis period.

[5]Table 6 is provided in Appendix 7.2.

5 Benchmark results

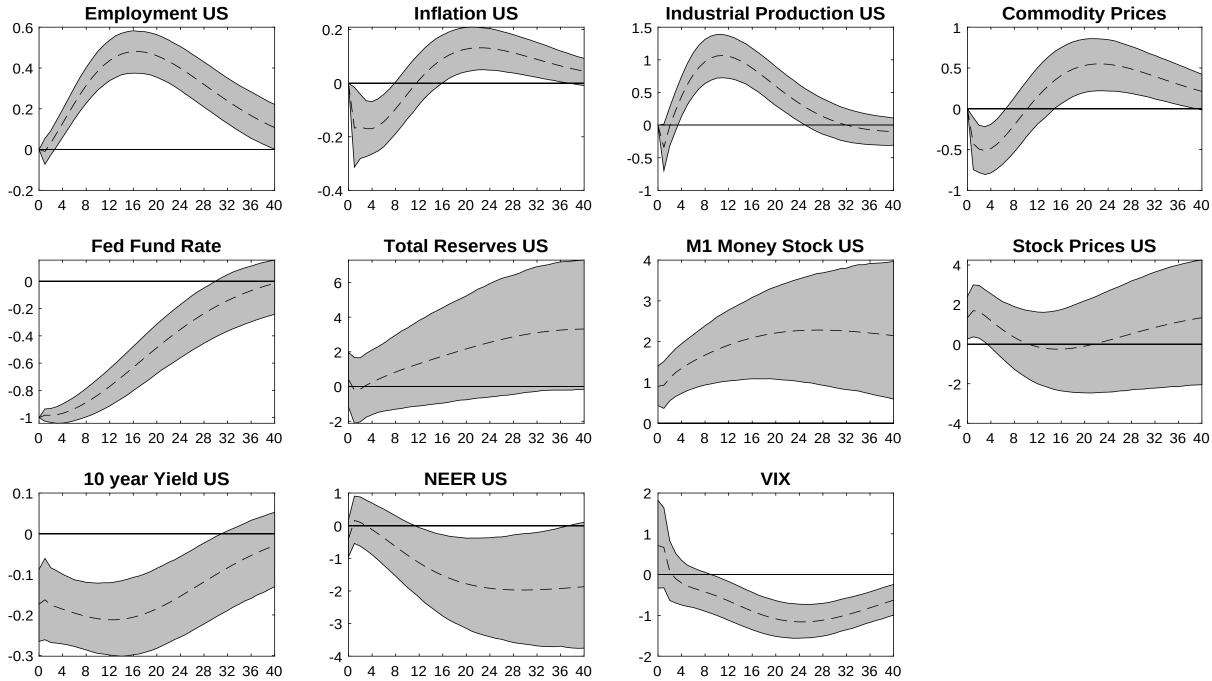
5.1 Impulse Response Functions Results for the Bayesian VAR analysis

We now present the results for the BVAR. To keep with the identification of monetary policy in Section 4.1, we separate our results by conventional and unconventional monetary policy. To save space, we only present selected variables relevant to our discussion. Results with all the variables are provided in Appendix 7.3.

5.1.1 Conventional monetary policy period

The results for monetary policy identification are obtained using a medium scale BVAR with 2 lags of the endogenous variables. The period under consideration is January 1990 to December 2008. We present the impulse response functions over 40 months. All figures show the responses of the variables to a negative one-standard deviation to a monetary policy shock (100 basis points) - an expansionary monetary policy. The shaded area represents the posterior coverage interval at 68% level. We start with the results for the identification of monetary policy in the US. To do this, we estimate an 11 variable BVAR model for the US. The model include the following variables in their order: employment, inflation, industrial production, commodity prices, the Fed rate, total reserves, M1 money stock, Standard Poor's stock price index as proxy for stock prices, yield on 10 year bond, nominal effective exchange rates, and the VIX index. The impulse response functions for this specification are presented in Figure 4. A one standard deviation shock induces a contemporaneous 1% decrease in the Fund rate. The response of economic activity is consistent with economic theory. Employment, industrial production and commodity prices increase. For the financial variables, an expansionary monetary policy in the US reduces global risk, consistent with Rey (2016). With risk low, the yield on long-term bonds decrease resulting in an increase in stock prices. The US dollar depreciates against it's major trading partners.

Figure 4: US conventional monetary policy identification - Pre-ZLB



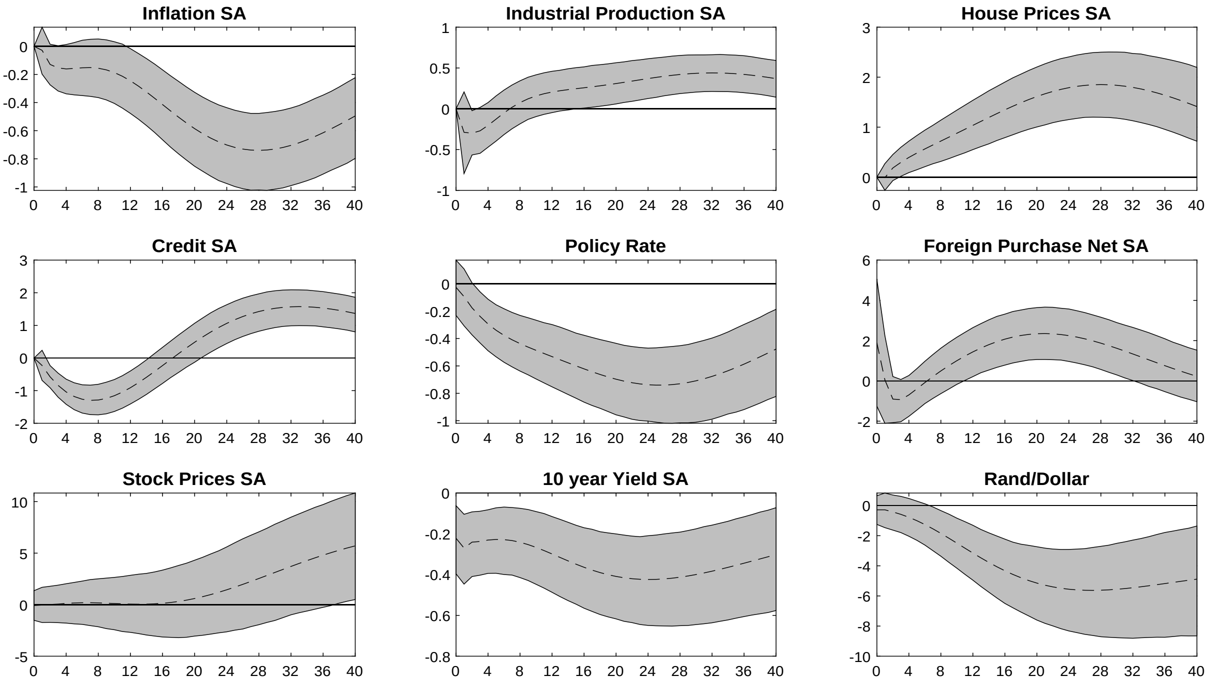
Note: The figure shows the impulse responses of US variables to a 1% increase in the Feds Fund rate during the period January 1990 and December 2008. The shaded area represent the posterior coverage interval at 68% level.

We then extend the US BVAR model with South African variables. These include industrial production, inflation, the US dollar and Rand exchange rate, yield on 10 year bond, house and stock prices, private sector credit, and the net purchase of shares by non-residents (as a share of total sales and purchases of shares by non-residents). This increases the number of variables in the model to 20. The results are presented in Figure 5. With the inclusion of the South African variables, our results for monetary policy identification in the US remain robust, see Figure 10 and 11 in the Appendix 7.3.1 for full results.

From Figure 5 and 6, we can see that an expansionary US monetary policy reduces the long-term rate in South Africa. The increase in net purchase of stocks by non-residents indicates capital flows from the US and other developed markets to emerging markets such as South Africa, and therefore an appreciation of the South African local currency against the US dollar. The response of stock prices is insignificant.

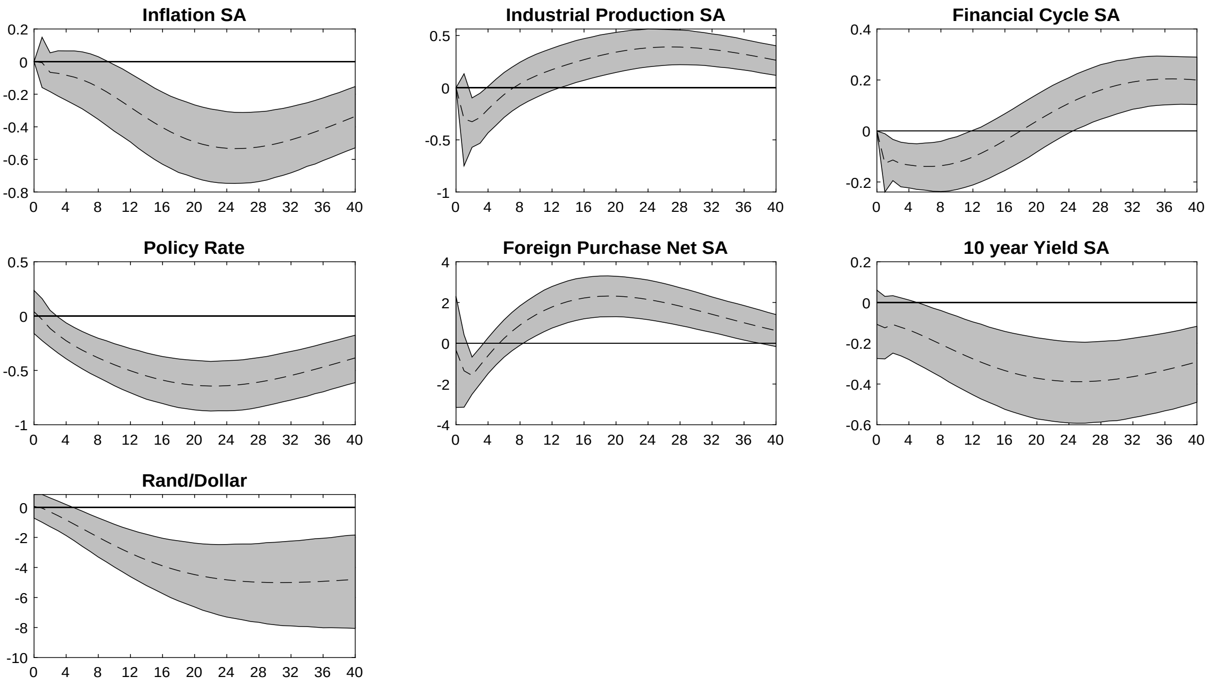
For the real economy, the appreciation of the local currency puts downward pressure on local inflation. Monetary policy eases to accommodate the decline in inflation. This stimulates local demand and therefore boosts industrial production. House prices and credit increase. These results remain the same even when we replace credit, stock and house prices with the financial cycle, as presented in Figure 6. The figure indicates that the financial cycle firstly decreases in the 12 months, before increasing. The initial decrease can be attributed to the decline in credit. This is consistent with the observed co-movement, during this period, of the financial cycle and credit in section 1.

Figure 5: Response of South African variables - Pre-ZLB



Note: The figure shows the impulse responses of South African variables to a 1% increase in the Feds Fund rate during the period January 1990 and December 2008. The shaded area represents the posterior coverage interval at 68% level.

Figure 6: Response of South African variables - Pre-ZLB (Financial cycle)



Note: The figure shows the impulse responses of South African variables, replacing credit, stock prices and house prices with the financial cycle, to a 1% increase in the Feds Fund rate during the period January 1990 and December 2008. The shaded area represents the posterior coverage interval at 68% level.

5.1.2 Unconventional monetary policy period

We now look at the response of South African variables to unconventional monetary policy in the US during the period January 2009 and February 2018. The results for monetary policy identification are obtained using a medium scale BVAR with two lags. Again, we start with the results for the identification of monetary policy in the US before including the South African variables. All figures show the response of the variables to a positive one-standard deviation to total assets of the US Federal Reserve Bank.

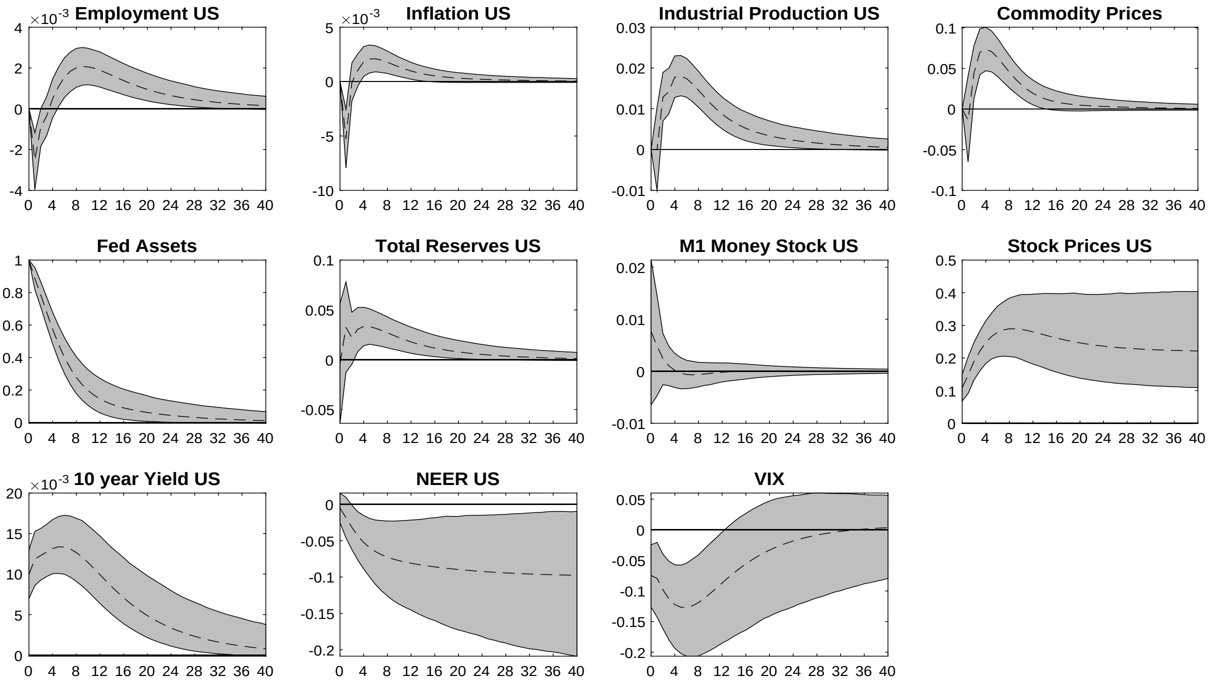
The impulse response functions for this specification are presented in Figure 7. A one standard deviation shock induces a contemporaneous 1% increase in Fed's assets. Even though we do not impose sign restrictions to the VIX, our results are consistent with Boeckx et al. (2017) and Gambacorta et al. (2014). Similar to the authors, the results indicate that an increase in the Fed's total assets lowered risk in financial markets, evidenced by the contemporaneous reduction in the VIX. With lower risk, activity in both the real economy and the financial sector increase in the US - output and inflation increase. Stock prices also increase whilst the US dollar depreciates against its major trading partners. Contrary to Boeckx et al. (2017), who impose a negative sign restriction to the long-term rate, we find that long-term rate in the US increases. This might indicate market expectation of an increase in expected inflation. Another possible explanation is lack of separation of the effects of forward guidance and assets purchases, since both unconventional monetary policy measures were employed during the period. Using a factor model to separate the two effects from each other, Swanson (2017) shows that forward guidance and large scale assets purchases have different effects on the yields on the 10 year US bonds during the period January 2009 and December 2015. The author finds that forward guidance has a positive effect on the yields on the 10 year US bonds while asset purchases has a negative effect. Weale and Wieladek (2016) also find that long-term rates increase for the US in three of their four monetary policy identification schemes when they use total assets.[6].

The depreciation of the US dollar against its major trading partners indicates capital outflows from the US to other countries. This is supported by our results for South Africa in Figure 9.

The results indicate a reduction in risk, with long-term rates decreasing. With lower global risk, both the South African stock prices and the net stock purchases by non-residents increase, resulting in an appreciation of the local currency against the US dollar. However, local products become uncompetitive - industrial production decrease. House prices increase whilst the decline of credit is insignificant. The results show an expansionary policy response to stimulate the economy. The results remain the same when we replace the components of the financial cycle with their aggregate measure in Figure 9. An expansionary monetary policy in the US improves the financial conditions in South Africa. From Figure 8, the increase in the financial condition seems to be driven by house prices and stock prices.

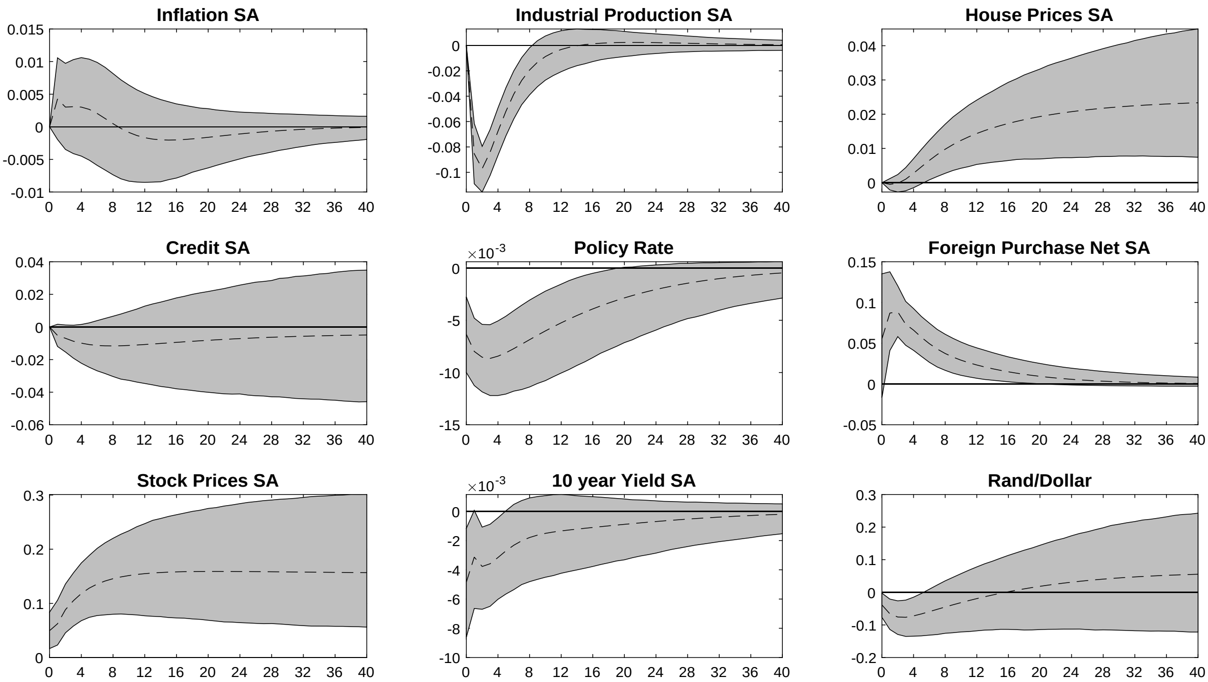
[6]See Figure C10 in the supplementary material.

Figure 7: US unconventional monetary policy identification - Post-ZLB



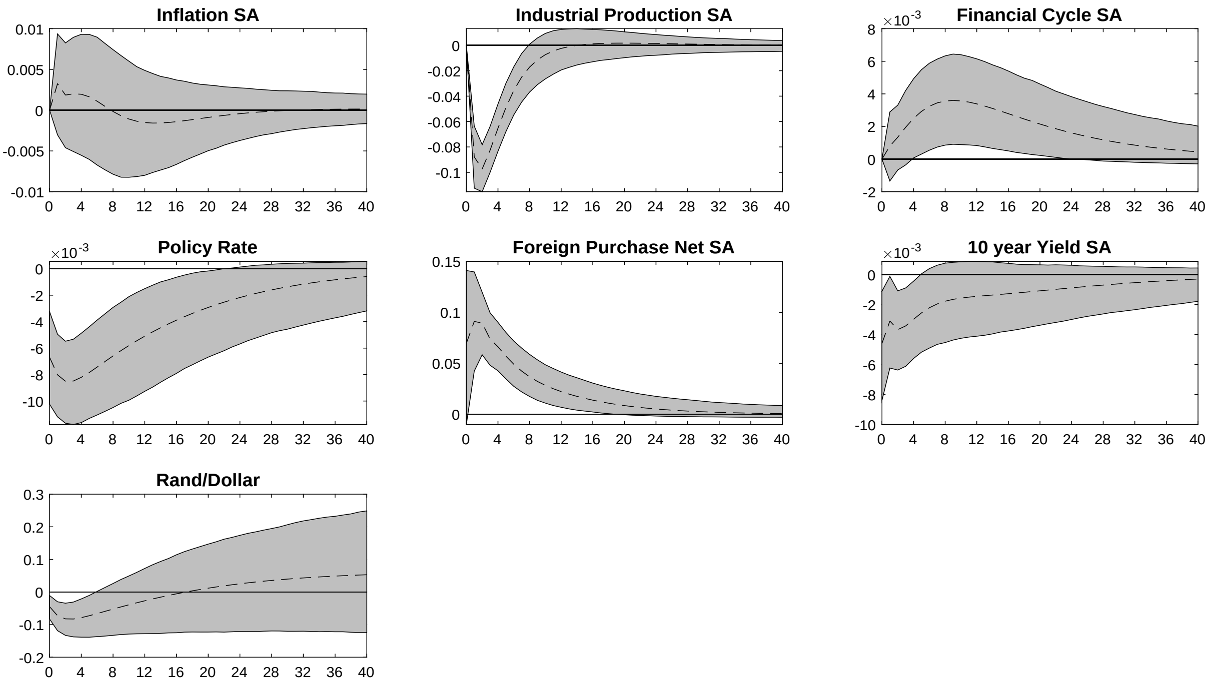
Note: The figure shows the impulse responses of US variables to an increase in the Feds total assets during the period January 2009 and February 2018. The shaded area represent the posterior coverage interval at 68% level.

Figure 8: Response of South African variables - Post-ZLB



Note: The figure shows the impulse responses of South African variables, replacing credit, stock prices and house prices with the financial cycle, to an increase in the Feds total assets during the period January 2009 and February 2018. The shaded area represent the posterior coverage interval at 68% level.

Figure 9: Response of South African variables - Post-ZLB (Financial cycle)



Note: Figure 8 shows the impulse responses of South African variables to an increase in the Feds total assets during the period January 2009 and February 2018. The shaded area represent the posterior coverage interval at 68% level.

How does this link to the trilemma or dilemma? The results indicate that policy rate in South Africa follows prices and output, in both periods, and is not affected by asset prices. Therefore monetary policy in South Africa is somewhat independent. However, from the results, we also see that industrial production and credit respond differently across the two periods. A stronger local currency should in theory reduce trade competitiveness of domestic goods. Such an effect would depend on the net effect between expenditure-augmenting and expenditure-switching, Bernanke (2017). An expansionary monetary policy in the US increases income of US economic agents and thereby increasing their demand for foreign goods like South Africa. This effect to the South African industrial production can either be direct if the US is a major export destination or indirect through the effect of the US on South Africa's major trading partners. Contrary to the pre-crisis or pre-ZLB period, where industrial production increase after an expansionary US monetary policy expansion, industrial production responds negatively. There are several potential reasons for this change in responsiveness. The first potential reason relates to the much discussed structural issues in the real sector in the second period which saw potential output decline from estimates of between 4-3.5% before the crisis to 2.8-1.9% after the crisis, Klein (2011), Fedderke and Mengisteab (2017) and Anvari et al. (2014) depending on the sample size and methodology. Issues include labour market rigidities, low quality of education and high unemployment levels among others. These issues were further exacerbated by policy and political uncertainty, negatively affecting business and consumer confidence, and dragging down private investment. Other factors prevailing during this periods include high indebtedness of households, which led to impaired balance sheets following the financial crisis and therefore deleveraging. Another factor relates to the change in regulations, such as Basel II, Basel III, and the Affordability Assessment Regulations (AARs) of the National Credit Regulator (NCR) which could have had a negative impact on the supply of credit. Whatever the reason (s), our results are consistent with the sluggish economic growth over the past decade in South Africa following the 2007-2008 global financial crisis, which has resulted in South Africa not being able to take advantage of low inflation nor the global economic recovery.

5.2 Variance Decomposition Results for the Bayesian VAR analysis

Table 1, 2, 3 and 4 report the variance decompositions from the estimated BVAR models in sections 5.1.1 and 5.1.2. Table 1 and 2 show the contribution of selected shocks to the variation of the South African monetary policy whilst Table 3 and 4 show the contribution of the US monetary policy shock to all the variables for chosen horizons for the South African monetary policy rate. The results are presented for pre- and post-ZLB for an easy comparison.

Starting with Table 1, we can see that the US monetary policy and South African industrial production and inflation shocks matter for the South African monetary policy. The increase in variation due to the South African industrial production during the second period, relative to that of inflation, indicate that the South African Reserve Bank was more accommodative to real activity post the crisis. These results remain the same even when we use the South African financial cycle in table 2. The results also indicate that the South African financial cycle shock is economically significant pre-ZLB, with the contribution of 2.25% in the first month to 10% in the second year for over two years.

Lastly, we can see in Table 3 and 4 the significant contribution of US monetary policy both to the US and South African variables. The results show that the variation of the 10 year US Treasury securities to US monetary policy shock more than doubled, with the shock accounting for just over a quarter of the variation. This is in line with the intention of the US quantitative easing to bring influence financial markets and long-term rates. The variation of the VIX due to US monetary policy is lower than in Rey (2016) where she found it to be 10% for the period 1990-2007, though this depended on the variables in the VAR.

South African financial variables portray a strong reaction in the second period, except the rand/dollar exchange rate. This is consistent even when we add the South Africa financial cycle. The foreign shock also accounts for more than 5% of variation for most South African variables at the 3 and 4 year horizons. These include inflation, industrial production and the policy rate. Taken together with the results for the impulse response function, the results indicate that there are some spillovers from the US to South Africa.

5.3 Robustness analysis

We test the robustness of our results against other model specifications. We consider the following specifications (i) using the shadow rate as a monetary policy instrument in both periods, (ii) only using US securities with longer term maturities, such as 5 and 10 year US Treasury and mortgage-backed instead of total assets for the post-ZLB period, and (iii) lastly using Feds announcements scaled by 2009Q1 nominal gross domestic product for the post-ZLB period. The latter specification follows Weale and Wieladek (2016). The authors use announcements for the US, scaled by the 2009Q1 nominal GDP to avoid endogeneity problems of using current GDP.[7] Given the similarity of the responses with financial cycle, we only focus on the results with components of the financial cycle. The results for the impulse response functions are provided in Appendices 7.4. Starting with the results for the shadow rates, we can see that a reduction in the shadow rate does reduce global risk with a lag. This reduces the yields on

[7] The authors also put weights to the announcements but do not give much details. Hence we take a simpler and non-weighted approach to their method.

Table 1: Variance Decomposition: Contribution of shocks to South African Policy Rate

	Pre-ZLB							Post-ZLB						
Horizon	1	3	6	12	24	36	48	1	3	6	12	24	36	48
Employment US	0.07	0.07	0.09	0.07	0.48	3.85	6.97	0.66	0.85	0.88	0.93	0.93	0.95	0.95
Inflation US	0.00	0.28	1.47	3.68	3.92	3.32	3.05	1.48	3.84	6.46	7.99	8.37	8.36	8.34
Industrial Production US	0.78	2.76	4.94	5.30	4.04	3.48	3.19	3.14	4.21	4.23	4.04	3.88	3.83	3.81
Commodity Prices	3.49	7.06	11.87	17.34	17.80	15.37	13.82	0.89	0.51	0.31	0.23	0.21	0.22	0.22
Inflation SA	0.43	0.44	0.33	0.21	0.95	2.04	2.15	0.13	0.08	0.07	0.06	0.05	0.05	0.07
Industrial Production SA	0.62	1.76	2.42	2.25	1.71	1.43	1.32	3.27	3.55	3.22	2.87	2.69	2.66	2.64
House Prices SA	0.02	0.04	0.14	0.27	0.22	0.21	0.30	0.06	0.04	0.11	0.20	0.24	0.25	0.25
Credit SA	0.02	0.08	0.08	0.19	1.35	1.53	1.40	0.11	0.10	0.12	0.14	0.15	0.15	0.15
Fed Fund Rate	0.01	0.15	0.60	1.82	5.54	8.73	9.28	2.27	4.75	6.32	7.55	8.23	8.29	8.27
Total Reserves US	0.36	0.25	0.17	0.11	0.31	0.84	1.55	0.10	0.69	0.82	0.82	0.82	0.82	0.81
M1 Money Stock US	0.06	0.05	0.06	0.06	0.05	0.04	0.04	0.14	1.07	1.21	1.25	1.29	1.31	1.32
Stock Prices US	0.11	0.08	0.07	0.05	0.04	0.04	0.05	0.08	0.85	1.18	1.25	1.17	1.16	1.20
10 year Yield US	0.31	0.22	0.39	3.27	8.43	10.57	11.83	0.09	0.32	0.44	0.42	0.38	0.38	0.40
NEER US	0.00	0.02	0.04	0.07	0.11	0.13	0.13	0.78	0.39	0.25	0.20	0.18	0.18	0.18
VIX	0.67	0.68	0.59	0.53	0.87	1.47	1.94	0.00	0.06	0.21	0.46	0.89	1.24	1.49
Policy Rate	93.07	85.47	75.61	62.57	50.71	42.80	38.32	86.79	73.51	63.51	57.25	54.95	54.48	54.25
Foreign Purchase Net SA	0.00	0.26	0.48	0.58	0.69	0.66	0.59	0.00	0.09	0.31	0.50	0.59	0.60	0.60
Stock Prices SA	0.00	0.02	0.01	0.02	0.03	0.02	0.03	0.00	0.01	0.02	0.02	0.03	0.03	0.03
10 year Yield SA	0.00	0.28	0.64	1.56	2.73	3.43	4.01	0.00	5.06	10.31	13.79	14.94	15.04	15.01
Rand/Dollar	0.00	0.02	0.03	0.04	0.03	0.03	0.06	0.00	0.00	0.00	0.00	0.01	0.01	0.01

Note: The table reports the contribution of US monetary policy to the forecast error variance for selected horizons (in months) for the South African policy rate.

Table 2: Variance Decomposition: Contribution of shocks to South African Policy Rate (including the Financial Cycle)

	Pre-ZLB							Post-ZLB						
Horizon	1	3	6	12	24	36	48	1	3	6	12	24	36	48
Employment US	0.00	0.00	0.00	0.05	0.27	2.16	3.89	0.59	0.78	0.85	0.98	1.05	1.08	1.09
Inflation US	0.01	0.27	1.24	2.81	2.76	2.35	2.17	1.40	3.71	6.31	7.99	8.52	8.55	8.54
Industrial Production US	0.48	1.82	3.19	3.15	2.33	2.00	1.89	3.20	4.19	4.13	3.84	3.62	3.57	3.55
Commodity Prices	3.38	6.80	11.17	15.49	15.50	13.75	12.76	0.81	0.47	0.30	0.22	0.19	0.18	0.18
Inflation SA	0.23	0.35	0.29	0.26	1.12	1.99	2.21	0.12	0.09	0.16	0.18	0.19	0.21	0.22
Industrial Production SA	0.05	0.38	0.64	0.60	0.45	0.39	0.37	3.33	3.43	2.97	2.51	2.28	2.24	2.23
Financial Cycle SA	2.25	3.91	6.11	8.64	9.77	10.01	10.05	0.04	0.07	0.33	0.87	1.28	1.36	1.38
Fed Fund Rate	0.01	0.07	0.42	1.77	6.07	8.94	9.56	2.50	4.94	6.49	7.76	8.52	8.63	8.63
Total Reserves US	0.33	0.25	0.18	0.12	0.17	0.39	0.73	0.08	0.62	0.76	0.76	0.76	0.76	0.76
M1 Money Stock US	0.04	0.04	0.04	0.04	0.03	0.03	0.02	0.08	0.92	1.07	1.11	1.12	1.13	1.14
Stock Prices US	0.16	0.25	0.31	0.25	0.19	0.16	0.15	0.06	0.79	1.15	1.26	1.20	1.18	1.20
10 year Yield US	0.90	0.87	0.60	2.48	7.28	10.05	11.41	0.07	0.30	0.42	0.40	0.35	0.36	0.37
NEER US	0.05	0.06	0.07	0.08	0.09	0.09	0.08	0.63	0.33	0.21	0.16	0.14	0.14	0.14
VIX	0.01	0.02	0.04	0.06	0.39	0.78	1.05	0.02	0.07	0.20	0.39	0.69	0.92	1.08
Policy Rate	92.10	84.13	74.09	61.68	49.88	42.69	39.24	87.08	74.33	64.68	58.27	55.57	55.04	54.84
Foreign Purchase Net SA	0.00	0.18	0.34	0.44	0.55	0.56	0.53	0.00	0.10	0.34	0.57	0.69	0.71	0.71
10 year Yield SA	0.00	0.58	1.27	2.08	3.14	3.65	3.84	0.00	4.85	9.65	12.75	13.81	13.93	13.92
Rand/Dollar	0.00	0.00	0.01	0.01	0.01	0.01	0.04	0.00	0.00	0.00	0.00	0.01	0.01	0.01

Note: The table reports the contribution of US monetary policy to the forecast error variance for selected horizons (in months) for the South African policy rate.

Table 3: Variance Decomposition: Contribution of US Monetary Policy shock

	Pre-ZLB							Post-ZLB						
Horizon	1	3	6	12	24	36	48	1	3	6	12	24	36	48
Employment US	0.00	0.02	0.54	4.91	13.28	12.15	11.73	0.00	0.30	0.46	1.54	2.07	2.09	2.09
Inflation US	0.00	0.15	0.43	0.57	1.00	1.41	1.43	0.00	0.54	0.81	1.01	1.04	1.04	1.04
Industrial Production US	0.00	0.04	0.21	1.84	3.34	3.23	3.39	0.00	0.21	1.10	1.98	2.11	2.11	2.11
Commodity Prices	0.00	0.34	0.83	0.95	1.81	3.00	3.32	0.00	0.14	0.78	1.05	1.07	1.07	1.07
Inflation SA	0.00	0.04	0.14	0.27	2.46	6.33	7.36	0.00	0.11	0.16	0.17	0.26	0.28	0.28
Industrial Production SA	0.00	0.07	0.11	0.13	0.43	1.08	1.48	0.00	6.20	9.65	9.87	9.80	9.80	9.80
House Prices SA	0.00	0.02	0.17	0.82	4.17	8.12	9.35	0.00	0.01	0.27	2.49	6.24	7.97	8.84
Credit SA	0.00	0.14	0.89	2.16	2.26	5.24	7.01	0.00	0.16	0.37	0.55	0.47	0.36	0.29
Fed Fund Rate	95.82	82.54	65.76	46.30	31.25	26.87	25.96	82.45	70.30	65.46	63.67	62.89	62.53	62.31
Total Reserves US	0.00	0.04	0.02	0.05	0.32	0.57	0.65	0.01	0.59	1.85	2.96	3.30	3.32	3.32
M1 Money Stock US	0.45	0.50	0.78	1.39	2.25	2.24	1.87	0.15	0.27	0.36	0.42	0.45	0.46	0.46
Stock Prices US	0.78	0.91	0.80	0.54	0.36	0.51	0.78	3.51	6.09	8.71	10.50	10.48	10.02	9.71
10 year Yield US	2.08	3.06	4.24	6.49	9.30	9.35	8.94	8.96	13.87	18.33	22.21	23.37	23.42	23.41
NEER US	0.27	0.12	0.14	0.46	1.52	2.18	2.51	0.57	1.69	2.60	2.71	2.03	1.58	1.31
VIX	0.06	0.06	0.05	0.12	1.14	2.55	2.86	0.59	1.05	1.50	1.62	1.31	1.11	1.01
Policy Rate	0.01	0.15	0.60	1.82	5.54	8.73	9.28	2.27	4.75	6.32	7.55	8.23	8.29	8.27
Foreign Purchase Net SA	0.13	0.13	0.14	0.19	1.15	1.69	1.69	0.36	1.99	3.24	4.00	4.23	4.25	4.25
Stock Prices SA	0.00	0.00	0.00	0.00	0.02	0.41	1.40	0.79	1.54	3.05	5.13	6.95	7.69	8.08
10 year Yield SA	0.53	0.85	0.96	1.30	3.14	4.66	5.15	0.84	1.05	1.39	1.53	1.65	1.68	1.68
Rand/Dollar	0.03	0.03	0.11	0.64	2.96	4.21	4.34	0.48	1.17	1.34	0.89	0.42	0.38	0.43

Note: The table reports the contribution of US monetary policy to the forecast error variance for selected horizons (in months) for all the variables in the model.

Table 4: Variance Decomposition: Contribution of US Monetary Policy shock (including the Financial Cycle)

	Pre-ZLB							Post-ZLB						
Horizon	1	3	6	12	24	36	48	1	3	6	12	24	36	48
Employment US	0.00	0.18	1.52	7.49	16.25	15.88	15.40	0.00	0.27	0.49	1.59	2.04	2.05	2.05
Inflation US	0.00	0.13	0.29	0.32	0.72	1.13	1.22	0.00	0.49	0.79	0.97	0.98	0.98	0.98
Industrial Production US	0.00	0.07	0.59	2.34	3.81	3.79	3.82	0.00	0.22	1.14	1.92	2.01	2.01	2.01
Commodity Prices	0.00	0.27	0.56	0.60	1.34	2.52	2.98	0.00	0.17	0.82	1.06	1.06	1.06	1.06
Inflation SA	0.00	0.01	0.04	0.26	2.46	5.04	5.84	0.00	0.06	0.08	0.09	0.13	0.13	0.13
Industrial Production SA	0.00	0.10	0.16	0.17	0.62	1.32	1.60	0.00	6.60	9.86	9.95	9.88	9.88	9.88
Financial Cycle SA	0.00	0.15	0.34	0.62	0.67	1.58	2.69	0.00	0.09	0.57	2.02	3.41	3.65	3.69
Fed Fund Rate	96.12	84.90	69.31	50.57	36.23	32.41	31.89	82.03	70.64	66.29	64.54	63.61	63.25	63.07
Total Reserves US	0.00	0.00	0.02	0.15	0.61	0.99	1.16	0.04	0.74	2.07	3.07	3.34	3.36	3.37
M1 Money Stock US	0.30	0.38	0.67	1.35	2.23	2.22	1.90	0.20	0.34	0.42	0.48	0.51	0.51	0.51
Stock Prices US	0.72	0.80	0.68	0.48	0.36	0.46	0.67	4.17	7.03	9.74	11.36	11.07	10.51	10.15
10 year Yield US	1.92	3.01	4.25	6.24	8.59	9.18	9.14	9.59	14.79	19.50	23.34	24.36	24.38	24.38
NEER US	0.35	0.25	0.37	0.83	1.90	2.61	2.98	1.14	2.81	4.07	4.11	2.86	2.04	1.57
VIX	0.02	0.04	0.04	0.15	1.43	2.59	2.88	0.76	1.29	1.76	1.82	1.44	1.22	1.10
Policy Rate	0.01	0.07	0.42	1.77	6.07	8.94	9.56	2.50	4.94	6.49	7.76	8.52	8.63	8.63
Foreign Purchase Net SA	0.00	0.14	0.17	0.33	1.66	2.40	2.47	0.60	2.40	3.72	4.50	4.71	4.72	4.72
10 year Yield SA	0.14	0.22	0.31	0.80	2.77	4.65	5.48	0.77	1.01	1.35	1.52	1.72	1.78	1.79
Rand/Dollar	0.00	0.01	0.15	0.92	3.21	4.57	5.01	0.74	1.61	1.82	1.25	0.57	0.46	0.48

Note: The table reports the contribution of US monetary policy to the forecast error variance for selected horizons (in months) for all the variables in the model.

10 year securities in both the US and South Africa. Stock prices also increase. However, the responses of real activity and inflation is not as expected and mainly insignificant, with employment, industrial production and prices declining. The results for using US securities with longer term maturities are mostly consistent with our benchmark results. Lastly, the results for Feds announcements indicate that an increase in announcement also reduce the yields on the US 10 year securities, but not for South Africa. Most of the responses for the South African variables are inconsistent with our benchmark results.

6 Conclusion

In this paper, we investigate the effect of US monetary policy on South Africa between January 1990 and February 2018. We start with a simple analysis of the South African financial cycle to the global financial cycle by Miranda-Agrippino and Rey (2018) and global financial market risk. We find a co-movement of the local cycle with the rest of the world, especially from 2002 onwards, as South African became a more open economy. We also find that an increase in global risk reduce financial conditions in South Africa.

We then assess the channels through which the US monetary policy is transmitted to SA. To do this, we use a large Bayesian vector autoregressive (LBVAR) model with Minnesota priors, proposed by Bańbura et al. (2010) covering the period ranging January 1990 to February 2018. In the pre-crisis period, from January 1990 to December 2008, we identify monetary policy shock from the US based on the conventional monetary policy. For the post-crisis period, from January 2009 to February 2018, we identify monetary policy shock from the US based on the unconventional monetary policy due to the zero-lower bound.

In both periods, we are able to identify monetary policy in the US. An expansionary conventional or unconventional monetary policy in the US reduces global risk and stimulates the real and financial sector in the US. The results for South African variables are also similar for most of the variables. In both periods, an expansionary conventional or unconventional monetary policy in the US reduces long-term rate, indicating a reduction in risk towards emerging markets assets. We also see an increase in net purchase of stocks by non-residents indicating capital flows from the US and other developed markets to emerging markets, and an appreciation of the South African local currency against the US dollar. Stock prices on the local stock market also increase. However, from the results, we also see that industrial production and credit to the private sector respond differently to an expansionary monetary policy shock in the US. Contrary to the pre-crisis or pre-ZLB period, where US monetary policy expansion has a positive effect on the real economy, we see that industrial production responds negatively to an expansionary US monetary policy shock. These results highlight the structural issues in the real sector in the second period.

Our results indicate that monetary policy in South Africa is somewhat independent, responding to local inflation, economic activity and financial conditions. However, the variance decomposition also indicates that the US monetary policy accounts for some variation of the South African policy rate.

These results highlight the structural issues in the real sector, political uncertainty and constrained households' balance sheets post the global financial crisis. Our results are consistent with the sluggish economic growth over the past decade in South Africa following the 2007-2008 global financial crisis, which has resulted in South Africa not being able to take advantage of the low inflation nor the global economic recovery.

References

Adrian, T. and Shin, H. S. (2009), 'Money, liquidity, and monetary policy', *American Economic Review* **99**(2), 600–605.

Alessi, L., Barigozzi, M. and Capasso, M. (2008), 'A robust criterion for determining the number of static factors in approximate factor models'.

Algu, Y. and Creamer, K. (2017), 'Evaluating South Africa's open economy', *South African Journal of Economics* .

Anaya, P., Hachula, M. and Offermanns, C. J. (2017), 'Spillovers of US unconventional monetary policy to emerging markets: The role of capital flows', *Journal of International Money and Finance* **73**, 275–295.

Anvari, V., Ehlers, N. and Steinbach, R. (2014), 'A semi-structural approach to estimate South Africa's potential output', *South African Reserve Bank Working Paper Series. WP/14* **8**.

Bai, J. and Ng, S. (2002), 'Determining the number of factors in approximate factor models', *Econometrica* **70**(1), 191–221.

Bańbura, M., Giannone, D. and Reichlin, L. (2010), 'Large bayesian Vector Auto Regressions', *Journal of Applied Econometrics* **25**(1), 71–92.

Bernanke, B. S. (2017), 'Federal Reserve policy in an international context', *IMF Economic Review* **65**(1), 5–36.

Blake, A. P., Mumtaz, H. et al. (2012), 'Applied Bayesian econometrics for central bankers', *Technical Books* .

Boeckx, J., Dossche, M. and Peersman, G. (2017), 'Effectiveness and transmission of the ECB's balance sheet policies', *International Journal of Central Banking* **13**(1), 297–333.

Borio, C. and Zhu, H. (2012), 'Capital regulation, risk-taking and monetary policy: a missing link in the transmission mechanism?', *Journal of Financial Stability* **8**(4), 236–251.

Bowman, D., Londono, J. M. and Sapriza, H. (2015), 'US unconventional monetary policy and transmission to emerging market economies', *Journal of International Money and Finance* **55**, 27–59.

Bruno, V. and Shin, H. S. (2013), Capital flows, cross-border banking and global liquidity, Technical report, National Bureau of Economic Research.

Bruno, V. and Shin, H. S. (2015), 'Capital flows and the risk-taking channel of monetary policy', *Journal of Monetary Economics* **71**, 119–132.

Calvo, G. A. (1998), 'Capital flows and capital-market crises: the simple economics of sudden stops', *Journal of applied Economics* **1**(1), 35–54.

Calvo, G. A. and Reinhart, C. M. (2002), 'Fear of floating', *The Quarterly Journal of Economics* **117**(2), 379–408.

Canova, F. (2007), *Methods for applied macroeconomic research*, Vol. 13, Princeton University Press.

Chamon, M. and Garcia, M. (2016), 'Capital controls in Brazil: effective?', *Journal of International Money and Finance* **61**, 163–187.

Christiano, L. J. and Fitzgerald, T. J. (2003), 'The band pass filter', *international economic review* **44**(2), 435–465.

Domanski, D., Ng, T. et al. (2011), 'Getting effective macroprudential policy on the road: eight propositions', *BIS papers* **60**.

Fedderke, J. W. and Mengisteab, D. K. (2017), 'Estimating South Africa's output gap and potential growth rate', *South African Journal of Economics* **85**(2), 161–177.

Gambacorta, L., Hofmann, B. and Peersman, G. (2014), 'The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis', *Journal of Money, Credit and Banking* **46**(4), 615–642.

Gerko, E. and Rey, H. (2017), 'Monetary policy in the capitals of capital', *Journal of the European Economic Association* **15**(4), 721–745.

Giovanni, J. d., Kalemli-Ozcan, S., Ulu, M. F. and Baskaya, Y. S. (2017), International spillovers and local credit cycles, Technical report, National Bureau of Economic Research.

Hatzius, J., Hooper, P., Mishkin, F. S., Schoenholtz, K. L. and Watson, M. W. (2010), Financial conditions indexes: A fresh look after the financial crisis, Technical report, National Bureau of Economic Research.

Hofmann, B. and Takats, E. (2015), 'International monetary spillovers'.

Kavli, H. and Viegi, N. (2017), 'Are determinants of portfolio flows always the same?-South African results from a time varying parameter var model', *South African Journal of Economics* **85**(1), 3–27.

Klein, N. (2011), Measuring the potential output of South Africa, Technical report.

Miranda-Agrippino, S. and Rey, H. (2018), 'US monetary policy and the Global Financial Cycle'.

Mundell, R. A. (1960), 'The monetary dynamics of international adjustment under fixed and flexible exchange rates', *The Quarterly Journal of Economics* **74**(2), 227–257.

Ng, T. (2011), 'The predictive content of financial cycle measures for output fluctuations'.

Obstfeld, M. (2015), 'Trilemmas and trade-offs: living with financial globalisation'.

Obstfeld, M. (2019), 'Global dimensions of US monetary policy'.

Obstfeld, M., Ostry, J. D. and Qureshi, M. S. (2019), 'A tie that binds: Revisiting the trilemma in emerging market economies', *Review of Economics and Statistics* **101**(2), 279–293.

Obstfeld, M., Shambaugh, J. C. and Taylor, A. M. (2005), 'The trilemma in history: tradeoffs among exchange rates, monetary policies, and capital mobility', *The Review of Economics and Statistics* **87**(3), 423–438.

Ostry, J. D., Ghosh, A. R., Chamon, M. and Qureshi, M. S. (2012), 'Tools for managing financial-stability risks from capital inflows', *Journal of International Economics* **88**(2), 407–421.

Rey, H. (2015), Dilemma not trilemma: the global financial cycle and monetary policy independence, Technical report, National Bureau of Economic Research.

Rey, H. (2016), 'International channels of transmission of monetary policy and the Mundellian trilemma', *IMF Economic Review* **64**(1), 6–35.

Swanson, E. T. (2017), Measuring the effects of Federal Reserve forward guidance and asset purchases on financial markets, Technical report, National Bureau of Economic Research.

Weale, M. and Wieladek, T. (2016), 'What are the macroeconomic effects of asset purchases?', *Journal of Monetary Economics* **79**, 81–93.

7 Appendices

7.1 Model and identification of shocks

Consider the following VAR (p) model:

$$Y_t = c + B_1 Y_{t-1} + ... + B_p Y_{t-p} + \nu_t \quad (4)$$

where $Y_t = (y_{1,t}, y_{2,t}, ..., y_{n,t})'$ is an $N \times 1$ vector of random variables, $c = (c_1, c_2, ..., c_n)'$ is a $N \times 1$ vector of the constants terms and ν_t' is a $N \times 1$ vector of the error terms with a covariance matrix of $E(\nu_t \nu_t') = \Psi$. Given the large dimension of the matrix Y_t, the VAR model is estimated using the Bayesian VAR (BVAR), Blake et al. (2012), Canova (2007) and Bańbura et al. (2010). The Bayesian VAR imposes prior restrictions on the parameters to be estimated, thereby reducing the the curse of dimensionality. The approach followed in this literature is to set the prior distribution using the "non-strict" Minnesota prior. The Minnesota prior assumes that the variables in Y_t follow an AR (1) process or a random walk. The prior assumes a random walk if the diagonal elements of the B_1 matrix = 1 and an AR (1) process if the variables in the vector Y_t are stationary. Making $\tilde{B_0}$ the mean of the prior for the VAR coefficients, then the prior distribution is, $p(B) \sim N(\tilde{B_0}, H)$, where the variance H is given by the following relations for the VAR coefficients b_{ij}: $(\frac{\lambda_1}{l^{\lambda_3}})^2$ if $i = j$, $(\frac{\sigma_i \lambda_1 \lambda_2}{\sigma_j l^{\lambda_3}})^2$ if $i \neq j$ and $(\sigma_1 \lambda_4)^2$ for the constant.

The subscript i refers to the dependent variable in the i^{th} equation and j to the independent variables in the equation. The variances of the error terms from the AR regressions are estimated via the ordinary least squares and their ratio, $\frac{\sigma_i}{\sigma_j}$, accounts for the differences in the units of measurement of different variables. The parameter l is the lag length and the λ's are parameters that control the tightness of the prior as follows. λ_1 controls the standard deviation of the prior of own lags, where $\lambda_1 \to 0$ has the effect of shrinking the diagonal elements of the B_1 matrix towards 0 and all other coefficients to zero. $\lambda_2 \in (0, 1)$ controls the standard deviation of the prior on lags of variables other than the dependent variable where $\lambda_2 \to 0$ shrinks the off-diagonal elements to 0. If $\lambda_2 = 0$, there is no difference between own lag and the lags of other variables. λ_3 controls the the degree to which lags higher than 1 are likely to be zero where as $\lambda_1 \to \infty$ coefficients on lags higher than 1 are shrunk to 0. Lastly, λ_4 controls the prior variance of the constant. The constant is shrunk to 0 as $\lambda_4 \to 0$.

The strict Minnesota prior assumes that the covariance of the residuals of the VAR is diagonal with the diagonal elements fixed using the error variance from AR regressions σ_i. The current practice is to replace the Minnesota prior with the Normal inverse Wishart prior. The prior assumes a normal prior for the VAR coefficients and an inverse prior for the covariance matrix. This prior allows the random walk aspect of the Minnesota prior on the coefficients to be used without having to impose a fixed and diagonal error covariance matrix. The prior for the VAR parameters are:

$$p(B_0|\Psi) \sim N(\tilde{B_0}, \Psi \otimes \bar{H}) \tag{5}$$

$$p(\Psi) \sim IW(\bar{S}, \alpha) \tag{6}$$

The matrix $\bar{H}$ is a diagonal matrix where the diagonal elements are defined as

$$(\frac{\lambda_0 \lambda_1}{\sigma_i l^{\lambda_3}})^2 \tag{7}$$

for the coefficients on lags, and

$$(\lambda_0 \lambda_4)^2 \tag{8}$$

for the constant. The matrix $\bar{S}$ is defined as a $N \times N$ diagonal matrix with diagonal elements given by

$$(\frac{\sigma_i}{\lambda_0})^2 \tag{9}$$

where λ_0 controls the overall tightness of the prior on the covariance matrix. All other priors are as already explained. However, with the normal inverse wishart, $\lambda_2 = 0$, which implies that the lags of dependent variable and of other variables are treated the same. Following the literature, we also implement the normal inverse Wishart prior using dummy variable. The advantage of this method is that it helps to incorporate the prior that the variables have unit root, Blake et al. (2012). Using T_d dummy variables Y_d and X_d, we regress Y_d on X_d to get the prior mean of the VAR coefficients b_0 and the sum of the squared residuals gives the prior scale matrix for the error covariance matrix S:

$$\begin{aligned} b_0 &= (X_d' X_d)^{-1}(X_d' Y_d) \\ S &= (Y_d - X_d b_0)'(Y_d - X_d b_0) \end{aligned} \tag{10}$$

The regression is equivalent to imposing the normal inverse Wishart prior

$$\begin{aligned} p(B|\Psi) &\sim N(\tilde{b_0}, \Psi \otimes (X_d' X_d)^{-1}) \\ p(\Psi) &\sim IW(S, T_d - K) \end{aligned} \tag{11}$$

where K is the number of regressors in each equation. We generate the dummy variables by:

$$Y_d = \begin{pmatrix} diag(\xi_1\sigma_1, \ldots, \xi_N\sigma_N)/\lambda \\ 0_{N\times(P-1)\times N} \\ \\ diag(\sigma_1, \ldots, \sigma_N) \\ \ldots \\ 0_{1\times N} \end{pmatrix}, X_d = \begin{pmatrix} J_P \otimes diag(\sigma_1, \ldots, \sigma_N)/\lambda & 0_{NP\times 1} \\ \\ 0_{N\times(NP)} & 0_{N\times 1} \\ \\ 0_{1\times N} & c \end{pmatrix} \quad (12)$$

where ξ_1 are the prior means for the coefficients on the first lags of the dependent variables (which can be different from 1) and $J_P = diag(1 \ldots P)$. Appending the data with the dummy variables we get $Y* = [Y; Y_d]$ and $X* = [X; X_d]$ with length $T* = [T; T_d]$. We can now re-write equation (13) as:

$$Y_t^* = c + B_1 Y_{t-1}^* ... + B_p Y_{t-p}^* + \nu_t^* \quad (13)$$

Now the conditional posterior distribution of the appended data is:

$$\begin{aligned} p(B|\Psi) &\sim N(vec(B*), \Psi \otimes (X^{*\prime}X^*)^{-1}) \\ p(\Psi) &\sim IW(S*, T*) \end{aligned} \quad (14)$$

where $B* = (X^{*\prime}X^*)^{-1}(X^{*\prime}Y^*)$ and $S* = (Y^* - X^*B*)'(Y^* - X^*B*)$. Furthermore, additional priors are imposed on the sum of coefficients to improve the forecasting performance, (Bańbura et al. (2010)). This is called "inexact differencing". To do this, we re-write equation 13 in an error-correction form:

$$\triangle Y_t = c + (I_n - B_1 - ... - B_p)Y_{t-1} + A_1 \triangle Y_{t-1} + ... + A_{p-1} \triangle Y_{t-p+1} + \nu_t \quad (15)$$

A VAR in first difference requires $(I_n - B_1 - ... - B_p) = 0$. Letting $\Pi = (I_n - B_1 - ... - B_p)$, we set a prior that shrinks Π to zero. To achieve this, "inexact differencing", we augment the first lines of equation 16 with the following:

$$Y_d = \begin{pmatrix} diag(\xi_1\sigma_1, \ldots, \xi_N\sigma_N)/\tau \end{pmatrix} \quad , X_d = \begin{pmatrix} J_P \otimes diag(\sigma_1, \ldots, \sigma_N)/\lambda & 0_{NP\times 1} \end{pmatrix} \quad (16)$$

where the hyperparameter τ controls the degree of shrinkage - shrinkage decreases as τ approaches inf. Following Bańbura et al. (2010), we set τ, which controls the degree of shrinkage, to a loose prior of 10λ. The overall shrinkage λ is set to match the fit of the simple three-VAR model estimated by the ordinary least squares method.

7.2 Data

Table 5: Data for section 3

Data	Description	Source
Eskom bonds	Yield on loan stock traded on the stock exchange: Eskom bonds (State owned utility)	SARB
REER	Real effective exchange rate of the rand: Average for the period for 20 trading partners - Trade in manufactured goods	SARB
Medium-term rates	Yield on loan stock traded on the stock exchange: Government bonds - 3 to 5 years	SARB
Long-term rates	Yield on loan stock traded on the stock exchange: Government bonds - 5 to 10 years	SARB
House prices	Absa house Price Index (2000=100). New and existing homes for all sizes	Quantec
Stock prices	JSE All Share Index	IMF
Commodity prices	Platinum, gold, coal and crude oil prices	IMF
M1, M2 & M3	Monetary aggregates / Money supply	SARB

Table 6: Large BVAR data transformation and ordering

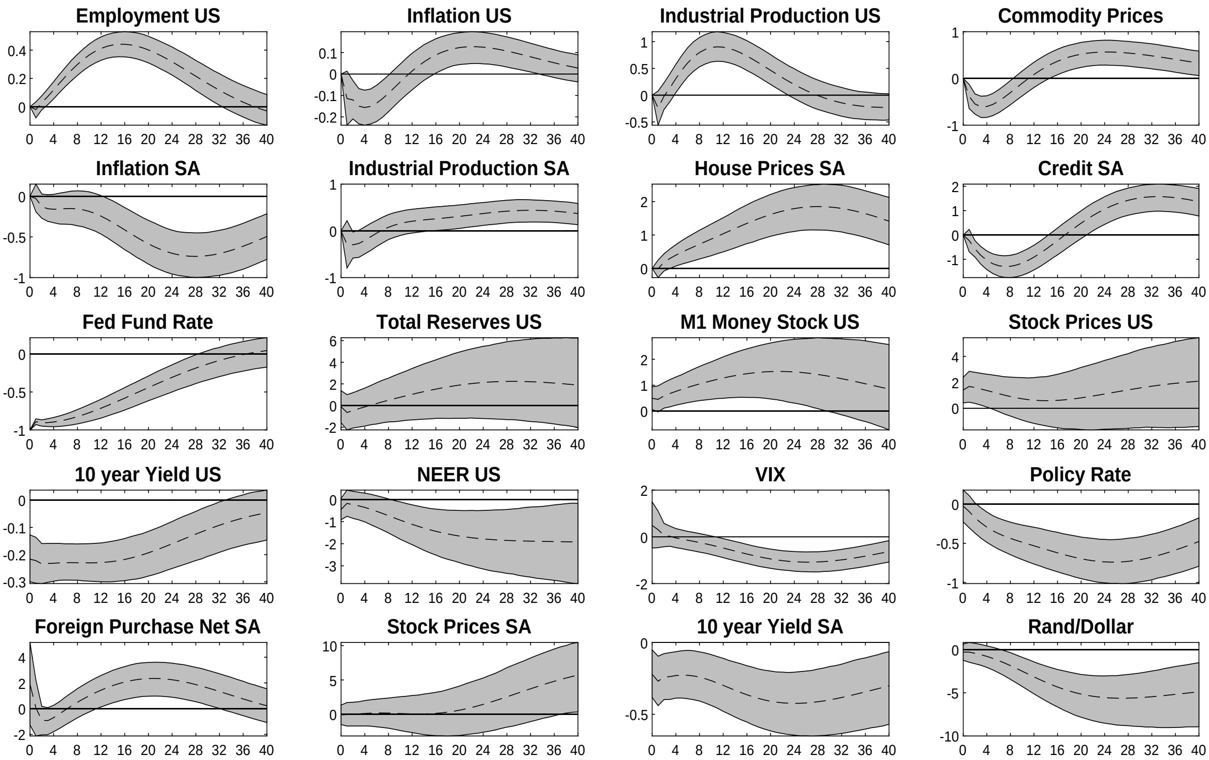
BVAR name	Description	Unit	S/F	Log	RW	CMP	UMP
Employment US	All Employees: Total Nonfarm Payrolls	Thousands of Persons	S	X	X	X	X
Inflation US	Consumer Price Index for All Urban Consumers: All Items	Index 1982-1984=100	S	X	X	X	X
Industrial Production US	Total index; s.a. IP	Index: 2012 - 100	S	X	X	X	X
Commodity Prices	Producer Price Index by Commodity for Final Demand: Finished Goods	Index: 1982=100	S	X	X	X	X
Inflation SA	CPI Headline	Index: 2016=100	S	X	X	X	X
Industrial Production SA	Manufacturing: Total volume of production; s.a.	Index: 2010=100	F	X	X	X	X
House Prices SA	Absa house Price Index. New and existing homes, all sizes	Index: 2000=100	S	X	X	X	X
Credit SA	Assets of banking institutions: Total deposits, loans and advances	Millions of Rand	S	X	X	X	X
Financial Cycle SA	Financial cycle from domestic house and stock prices and credit growth	Index	S	X	X	X	X
Fed Rate	Federal funds effective rate	Percent	MPV		X	X	
Fed Assets	Total assets less eliminations from consolidation: Wednesday level	Millions of Dollars	MPV		X		X
Total Reserves US	Total Reserves of Depository Institutions in 2000 prices	Billions of Dollars	F	X	X	X	
Stock Prices US	Standard & Poor's share price index	Index	F	X	X	X	X
10 Year Yield US	Market yield on U.S. Treasury securities at 10-year constant maturity	Percent	F	X	X	X	X
NEER US	Nominal broad Dollar index	Index	F	X	X	X	X
VIX	CBOE volatility index	Index	F	X	X	X	X
Policy Rate SA	Bankrate (lowest rediscount rate at SARB)	Percent	MPV		X	X	X
Stock Prices SA	JSE All Share Index	Index: 2010=100	F	X	X	X	X
Rand/Dollar	Nominal exchange rate of the rand: Average (20 trading partners)	Percentage	F	X	X	X	X
Foreign Purchase Net SA	Net purchases of shares by non-residents on the JSE	Millions of Rand	F	X	X	X	X

Note: Table 2 provides the list of the variables included in the BVAR models. The variables in the model are in the same order as in the table. The first column shows the code of the data by the source. The second and third columns shows (respectively) the short names and description of the variables used n the BVAR model estimation. The fourth column shows the unit of measure where Dollars is the US dollars and the Rand is the South African currency. The fifth column indicate whether the variable is slow moving (S), fast moving (F), or a monetary policy variable (MPV). Column six indicate if the variable is in logarithms and column seven if the variable is a Random Walk. Columns eight and nine indicate whether the variable is included in the conventional monetary policy (CMP) BVAR or the unconventional monetary policy (UMP) BVAR.

7.3 Additional results

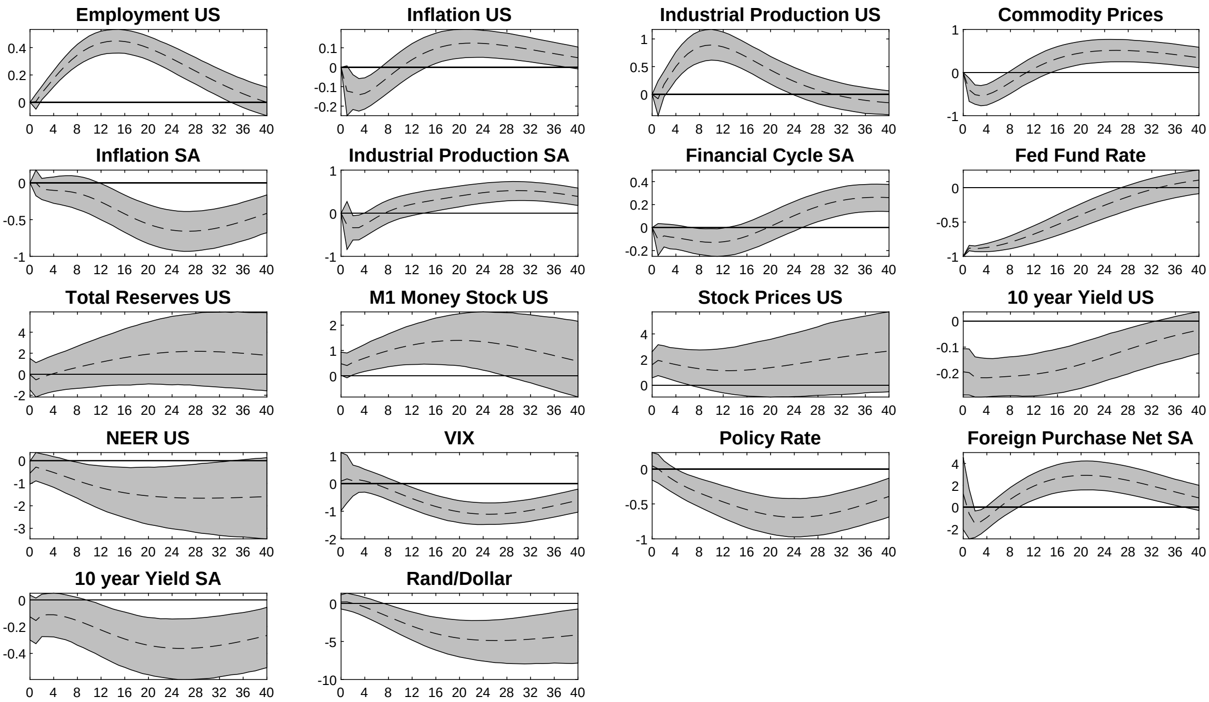
7.3.1 Full results

Figure 10: Response of all the variables - Pre-ZLB (all variables)



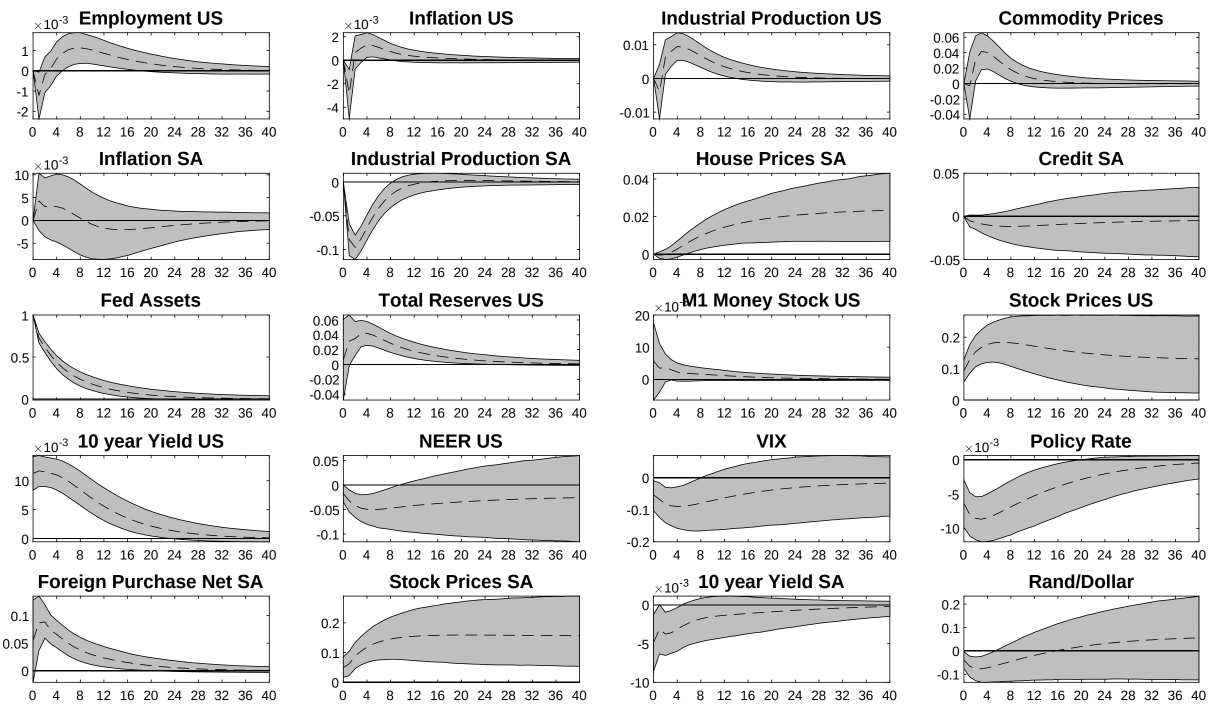
Note: Figure 10 shows the impulse responses of South African variables to an increase in the Feds total assets during the period January 1990 and December 2008. The shaded area represent the posterior coverage interval at 68% level.

Figure 11: Response of all the variables - Pre-ZLB (Financial Cycle)



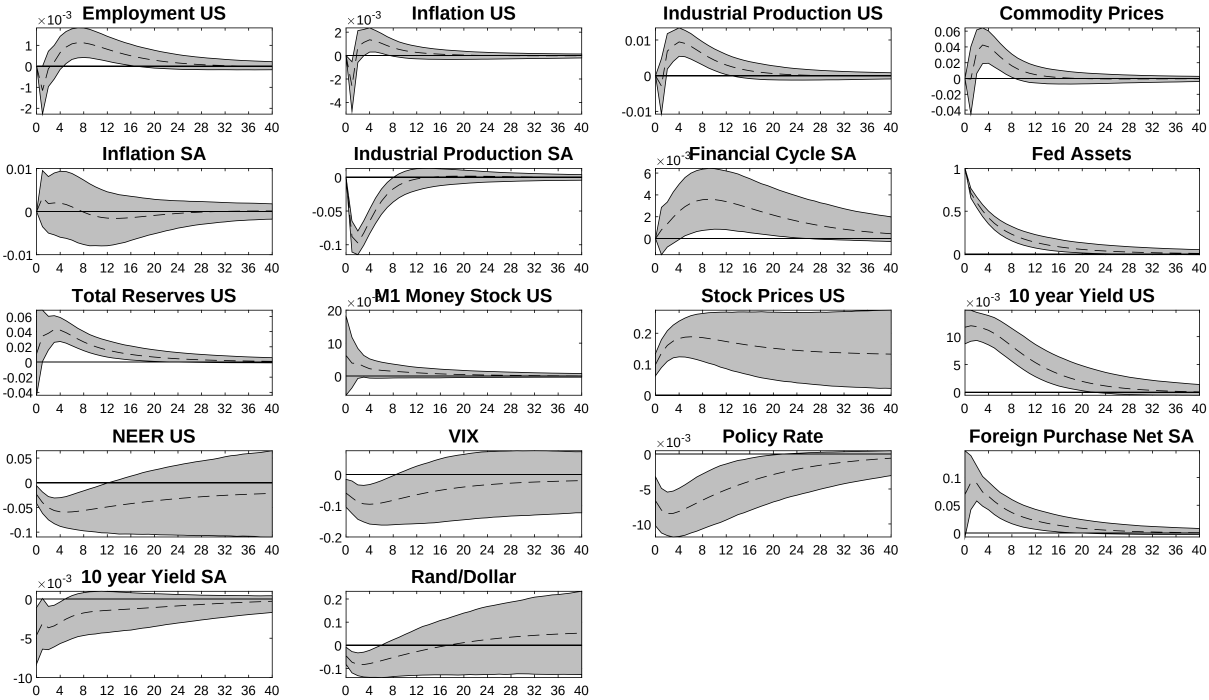
Note: Figure 11 shows the impulse responses of South African variables, replacing credit, stock prices and house prices with the financial cycle, to an increase in the Feds total assets during the period January 1990 and December 2008. The shaded area represent the posterior coverage interval at 68% level.

Figure 12: Response of all the variables - Post-ZLB (all variables)



Note: The figure shows the impulse responses of South African variables to an increase in the Feds total assets during the period January 2009 and February 2018. The shaded area represent the posterior coverage interval at 68% level.

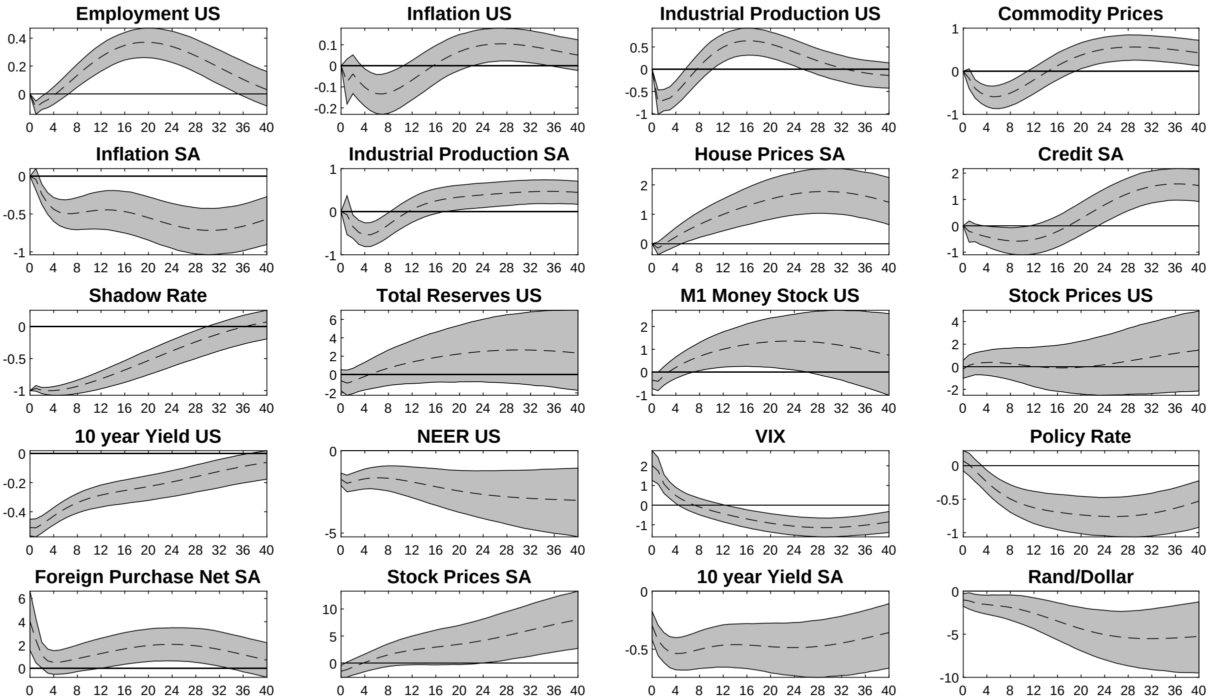
Figure 13: Response of all the variables - Post-ZLB (Financial Cycle)



Note: The figure shows the impulse responses of South African variables to an increase in the Feds total assets during the period January 2009 and February 2018. The shaded area represent the posterior coverage interval at 68% level.

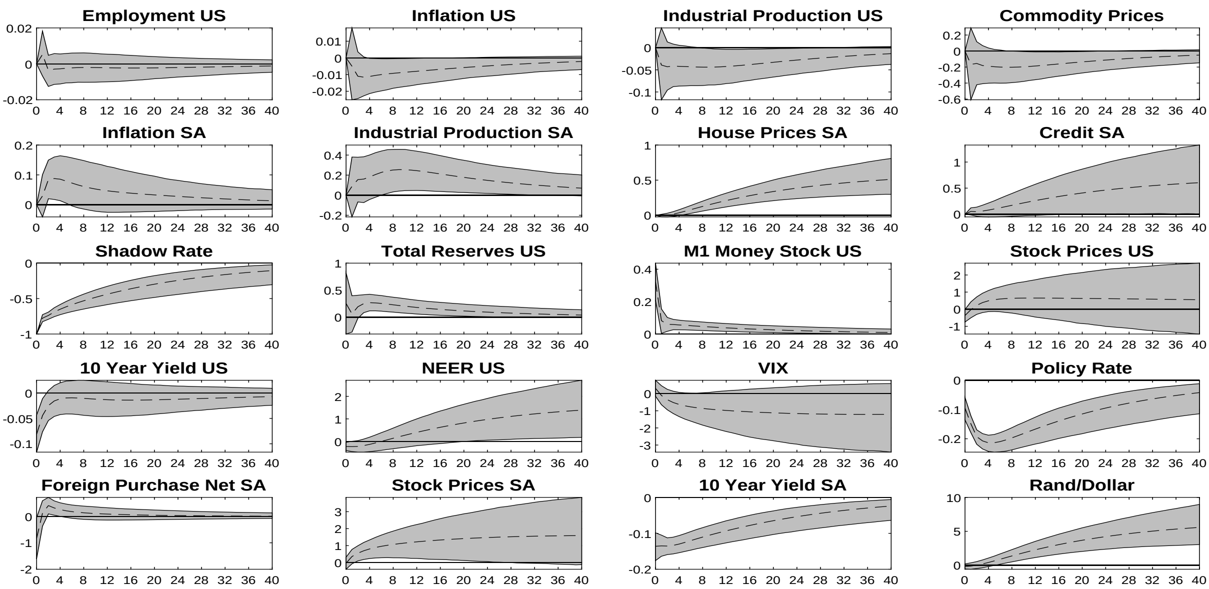
7.4 Robustness results

Figure 14: Responses of all the variables - US Shadow Rate (Pre-ZLB)



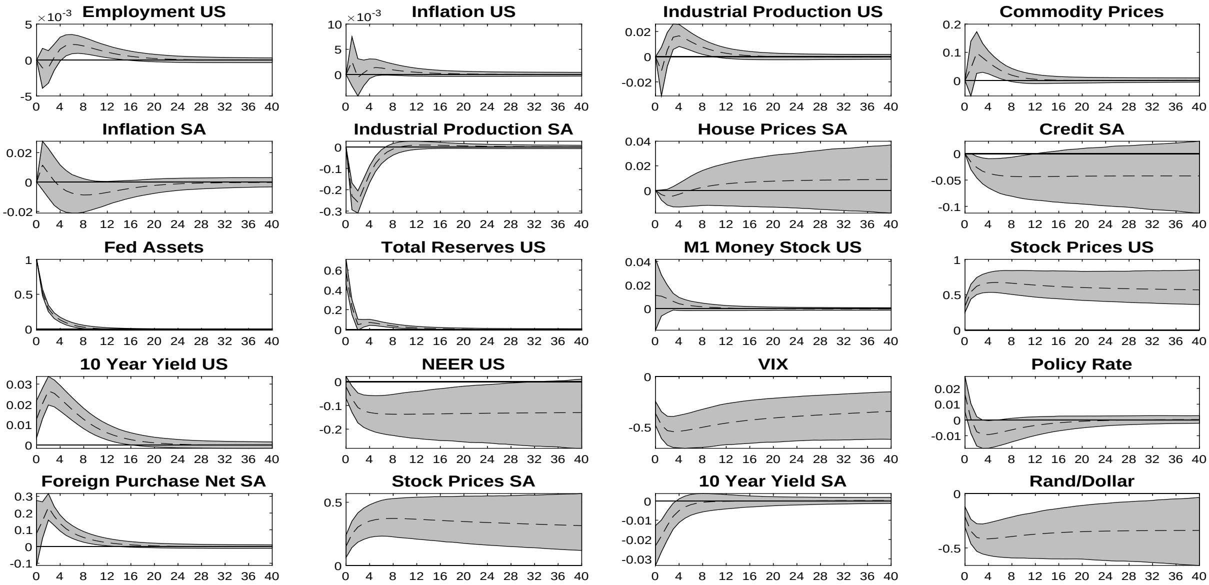
Note: The figure shows the impulse responses of US and South African variables to a reduction in the US Shadow rate during the period January 1990 and December 2008. The shaded area represent the posterior coverage interval at 68% level.

Figure 15: Responses of all the variables - US Shadow Rate (Post-ZLB)



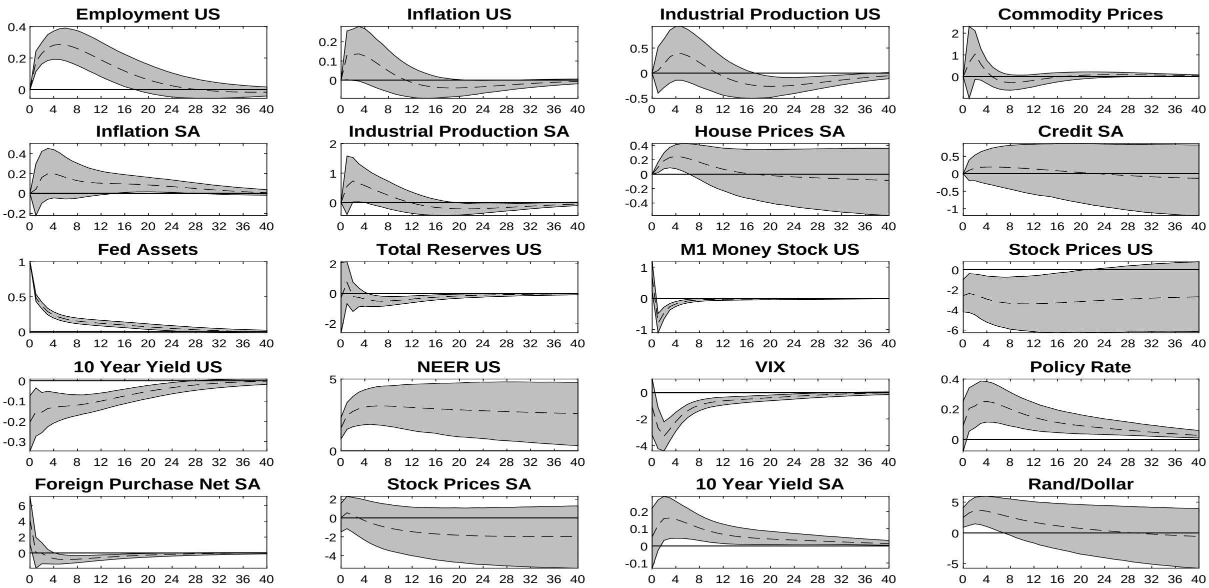
Note: The figure shows the impulse responses of US and South African variables to a reduction in the US Shadow rate during the period January 2009 and February 2018. The shaded area represent the posterior coverage interval at 68% level.

Figure 16: Response of all the variables - US Treasury and Mortgage-Backed Securities



Note: The figure shows the impulse responses of US and South African variables to an increase in the Feds' 5 and 10 year US Treasury and mortgage-backed securities during the period January 2009 and February 2018. The shaded area represent the posterior coverage interval at 68% level.

Figure 17: Responses of all the variables - Feds's Announcements



Note: The figure shows the impulse responses of US and South African variables to an increase in the Feds's announcements as a percentage of 2009Q1 nominal GDP during the period January 2009 and February 2018. The shaded area represent the posterior coverage interval at 68% level.