Do BRIC Countries respond to Global Financial Stress in their Monetary Policy Settings? : A Time Varying Policy Analysis

by

Nimantha P. Manamperi
Texas Tech University, Lubbock, Texas

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ABSTRACT

This Paper investigates the responsiveness of the BRIC countries (Brazil, Russia, India and China) monetary policy settings to different financial stress conditions over the last two decades. The International Monetary Fund’s emerging country financial stress index along with its sub components; Banking Stress, Security market Stress and Exchange Rate Stress is used to measure the financial stress in BRIC countries. A time varying coefficient model for a forward looking monetary policy rule is used to estimate the results. The estimation was preceded via a varying coefficient (VC) estimation technique and the results were confirmed by a Heckman Type (1976) two step Kalman Filter maximum likelihood procedure. The initial results suggested the money supply over the official interest rate as the most effective monetary policy tool for BRICs. The main results found that the BRIC country central banks loosen the monetary policy during higher financial stress periods and heavily responded to the exchange rate stress over the other two sub stresses. Moreover the financial stress effect on the monetary policy setting was insignificant at normal economic conditions. However the financial stress effect was considerably higher during local and regional economic and financial crises than that during global financial crises.

Keywords: Financial Stress, Taylor Rule, McCallum Rule, Monetary Policy, BRIC Countries, Time Varying Parameter Model, Endogeneity

JEL Classification: E42, E52, E58,

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1 Department of Economics, Texas Tech University, P.O Box 41014, Lubbock, TX 79409-1014
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1. Introduction

The initial dilemma caused by the collapse of the US mortgage lending market in 2007 later created a devastating global financial crisis with an enormous amount of economic, political and social problems in both advanced and emerging countries in the world. Initially this crisis influenced the advanced economies but after an initial period of pliability it has been transferred to the emerging economies (IMF World Economic Outlook April 2009). The developments in the emerging country financial markets were slowed down as the capital inflows were significantly disrupted (Balakrishnan et al. 2009). In addition, the slowdown in the exports and foreign worker remittances also transmitted the crisis effects in to the emerging countries (Mogan 2009).

These issues forced the households to take possible actions to overcome the negative influences of the crisis. Households cut unnecessary spending, planed their budgets appropriately while the policy makers made significant policy changes to overcome the complex issues (Chai, Maurer, Mitchell and Rogalla 2011). The 2007 - 2009 financial crisis also raised new set of challenges on the suitability of the existing central banking policies (Borio and Drehmann 2009). As a result, most advanced country central banks including US Fed and Bank of England set the official interest rates at historical low levels after the crisis (Baxa, Horvath and Vasicek 2012). In addition, some of the developed country central banks had to switch their regular conventional monetary policies to unconventional monetary policies such as a deviation from the interest rate policy rule to a balance sheet policy rule, to face the unpredictable shocks of the financial crisis (Gertler 2010).

Although most of the theoretical studies disagree on considering the financial crisis effect in to the central bank monetary policy settings, some economists have proved the financial instability as an influencing factor in all most all forms of monetary policy settings (Mishkin 2009 and Baxa, Horvath and Vasicek 2012). Baxa, Horvath and Vasicek showed that the monetary policy makers in the developed world had considered the global financial stress in their monetary policy settings using a financial stress index developed for the advanced economies by the IMF. The results of their paper showed that during the financial crises the central banks in US, Australia, Canada and Sweden maintained the interest rate policies approximately 50-100 basis points lower than in the non-crisis time. They also identified the relationship of the advanced country monetary policy
actions with the sub components of the main financial stress index; banking stress, security
market stress and exchange rate stress and found that the advanced country monetary policies
were more sensitive to banking stress and stock market stress than the exchange rate stress.

Unlike the advanced countries in the western world, the emerging countries such as BRICs indirectly
suffered from the 2008 global financial crisis (Balakrishnan et al. 2009). As a result the economic growth
and many other positive economic performances in these countries were reduced significantly. The
literature shows some evidence on the effects of the financial stress on the emerging market
economic growth. Most of the research identified a negative relationship between them (Lipsky
2008 and Brooman 2009). But no literature can be found on evaluating the impact of the financial
stress on the emerging market monetary policy settings. This paper addresses that gap in the
emerging country financial stability literature by implementing the transmitted advanced country
financial stress in to monetary policy rules in selected emerging countries, BRICs (Brazil, Russian
Federation, India and China).

Appendix 5 provides the time flow of important macro-monetary policy variables for BRICs. In
Brazil, the Industrial Production index was dropped over 25 percentage points during September
2008. The exports have also been dropped significantly during that period. The GDP growth rate
was dropped from 113% to an average of 46.72% during September 2008. The SELIC rate was
brought to the historical low of 8.75% after 2009. However the M2 growth rate was increased to
3.63% on average during the 2008 financial crisis. In Russia, the Industrial Production index was
dropped over 10 percentage points in September 2008. The exports have also been dropped
significantly during that period. In September 2008, the GDP growth rate was dropped to -9.4%
from an average of 30% before the crisis. The bank rate was brought to the historical low of
7.75% after 2010. However Russia maintained an 11% bank rate during the 2008 financial crisis.
In addition, the M2 growth rate was reduced to -11.91% in January 2009. In India, both the
Industrial Production index and the exports have been decreased during 2008 global financial
crisis. The GDP growth rate shows negative values during 2008 crisis. The bank rate stays at a
lowest of 6% since 2003. So there was no change in the bank rate during the 2008 crisis. The M2
growth rate has been increased during the 2008 financial crisis and those higher values lasted
throughout the entire crisis. In China, the Industrial Production index has been dropped to a
lowest of 2.1% during 1997 Asian financial crisis and 5.5% in 2008 global financial crisis. The exports have been dropped significantly during the 2008 financial crisis. The GDP growth rate dropped to 9.3% during 1997 Asian financial crisis and to 9.4% during 2008 global financial crisis. The bank rate was brought to the historical low of 2.79% during the 2008 financial crisis. China also experienced a significant drop in the Bank rate in 1997 Asian Financial crisis. In addition, the M2 growth rate has been increased on average to 4.4% during the 2008 financial crisis. Therefore monetary policy tools during financial crises. The significant changes in the monetary policy tools during the financial crises open up the question whether the financial crises influence the monetary policy in BRICs or not? This paper mainly targets finding answers for the following two questions; (1). Does the Financial stress Influences the Monetary Policy? , (2). Do BRIC Countries consider the financial stress in their monetary policy settings?

2. BRICs

According to Dow Jones August 2011 classifications, there are 21 emerging markets in the world. But my study focuses only on the BRIC countries; Brazil, Russia, India and China. These countries were originally grouped in to BRICs by Goldman Sachs’s James O’Neal. BRIC countries are formed because of their crucial role in the today’s world economy (Molano 2009). BRICs matter because of their significant economic weight in the world economy. The Figure 1 highlights the importance of the BRICs in the world’s future economy as they may become the largest economies in the world by 2050 (Glodman Sachs²). The economic growth rates for these countries are well above the most of the industrialized countries like USA, Japan, United Kingdom and Canada. During 2002 – 2008, the Chinese economy grew at an average of 10 percent per year while India grew at an average of 8 percent per year (Molano 2009). China also gradually became the world’s largest exporter with $1,897 trillion worth of exports (CIA’s The Worlds Fact book 2011). Meanwhile, the BRICs are also increasing their trade with one another: especially the Chinese and Indian trade has increased by $60 billion in 2010 while setting a $100 billion bilateral trade target by 2015.

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The BRICs’ large share of foreign exchange reserves in the world economy provides them a strong competitive advantage. All four countries are among the ten largest accumulators of foreign exchange reserves in dollars, accounting for over 40 percent of the world’s total ("The trillion Dollar Baby", The Economist Magazine February 2012). China also is the world’s second largest net creditor after Japan. Some economists argue that in few years the BRICs will represent one fifth of the global economy and in two decades will overtake the G7 countries (Almeida 2009). Besides the economic powers, the population and geography powers also provide the BRICs a significant standing in the world economy. In demographic provisions, BRICs includes the world’s two most populated countries and another two with sizeable populations. Currently China holds a fifth of the world population while India accounts for 17.5 percent of the world population. Brazil and Russia together carry more than 8 percent of the world population (World Bank Data Base 2011). The large population factor provides these economies to obtain the comparative advantage in the international trade by being low cost producers. Also Goldman Sachs predicted that these countries will increase the world consumption by having an increased middle class population in the coming years (Liaw 2012). This motivates the foreign investors in obtaining better market shares in those countries to be more profitable in sales. Moreover Russia’s 17 million km², China’s 9.3 million km², India’s 3.2 million km² and Brazil’s 8.5 million km² land
capacity provide BRICs with additional comparative advantage in order to be powerful in natural resources. These factors increased the BRICs’ notable impact on the global economy (The CIA World Fact Book 2011). The rising middle class and massive spending in infrastructure provide favorable opportunities for investment banks in the BRICs (Liaw 2012). Further the positive movements in the stock indexes, especially the Russian and Chinese stock markets, influenced the world financial analysts to pay more attention on them. The Economist Magazine in 2012 from its report “The Trillion Dollar Club” has revealed that this group may be in a position to challenge the role of the IMF and World Bank and also can make abandon attempts to increase free trade or even just ride roughshod over aid situations in poor countries. The BRICs also discussed the possibility of inventing a common central bank and a common currency during its 2012 general meeting. This can be a significant factor in the global economic activities. Moreover the monetary policy actions of BRICs can influence the rest of the world as they hold a large portion of treasury bonds of many of the foreign countries including the US, UK and Canada. All these above factors make the BRICs highly important in the world economy. So having a better idea about the monetary policy behavior of the BRICs would help other economies to be efficient in their participation in the world economic activities (Tamazian 2009).

3. THE FINANCIAL STRESS

There are different types of methods available to quantify the financial stress in the financial stability literature. Some of the empirical studies used “zero-one” binary framework to represent the crisis and non-crisis. However this approach raised some practical issues on differentiating a crisis from a non-crisis since it does not have a precise way of materializing magnitude of a crisis. The binary methodology was criticized by for this issue in the financial stability literature (Goldstein et al. 2000 and Balakrishnan et al. 2009). Most of the other financial crisis indexes focus on banking, currency and debt crisis and almost pay no attention on the security market stress (Cardarelli, Elekdag and Lall 2009). But nowadays the exploration of the entire financial system is a major requirement as the security market and the banking sector are more tangled.

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The Bank Credit Analyst (BCA)\(^4\) provides a monthly financial stress index for US using the performance of the banking shares to the world stock market, consumer confidence, slope of the yield curve and credit spreads. But this measure only represents one of the main three sectors in the financial market, the banking sector. The JP Morgan’s Credit Volatility Index (LCVI)\(^5\) focuses only on the banking sector and the exchange rate sector (Baxa, Horvanth and Vasic 2012). The Chicago Board of Exchange’s VIX index\(^6\) measures only the stock market volatility. One of the first comprehensive financial stress indexes was developed for Canada in 2006. It used the information from equity, bond, banking sector and foreign exchange market (Illing and Liu 2006). Later the Federal Reserve Bank of Kansas created the Kansas City financial stress index (KCFSI)\(^7\) to measure the financial stress in the US (Hakkiko and Keeton 2009). The IMF has generated a comprehensive financial stress index for advanced countries by considering all three sub sectors in the financial market and was named as AE-FSI (Cardarelli, Elekdag and Lall 2009). The banking sector stress was materialized using the slope of the yield curve, TED spread, Treasury Bill and Eurodollar spread; The difference between the interest rates on interbank loans and on government Treasury Bills) and the beta of the banking sector stocks in the Capital Asset Pricing Model (Sharpe 1964). The security market stress was constructed using corporate bond spreads, stock market returns and time varying volatility of stock returns. The exchange rate market stress was materialized by the changes in the nominal exchange rates. The construction of the AE-FSI inspired Balakrishnan et al., to develop a new index to measure the impact of the transmitted advanced country financial stress on the emerging markets. This index was later named as the IMF Emerging Market Financial Stress Index (EM-FSI). It consists of four market-based price indicators: the banking sector beta to measure the banking sector stress; sovereign spreads, stock market returns and stock market volatility to measure the security market stress; and the exchange market pressure index to measure the stress in the exchange Market. So I employ the EM-FSI as the principle measure of the transmitted financial stress from advanced to emerging countries.


\(^5\) LCVI : [http://www.jpmorgan.com/pages/jpmorgan](http://www.jpmorgan.com/pages/jpmorgan)


\(^7\) KCFSI : [http://www.kc.frb.org/research/indicatorsdata/kcfsi/](http://www.kc.frb.org/research/indicatorsdata/kcfsi/)
3.1. **THE EMERGING COUNTRY FINANCIAL STRESS INDEX (EM-FSI)**

The EM-FSI consists with five sub-variables which can represent the three main financial market segments in an economy; Banking, Security, and Exchange Markets. The five sub components are the banking sector beta ($\beta$), stock market returns, time varying stock market return volatility, sovereign debt spread and exchange market pressure index (EMPI). The EM_FSI is a combined measure of the above sub-indexes and observes the price variations in the three sub market segments relative to former trends as it provides closer look at the financial market. A variance equal weighting method is used to aggregate the sub-indexes in to EM_FSI. In this regard, all the variables were demeaned and weighted by the inverse of their variances as proposed by Kaminsky and Reinhart in 1999. This weighting method is widely used in the literature and provides an opportunity to adjust the EM_FSI index to different market volatilities (Balakrishnan et al. 2009). In general, the aggregation of the EM_FSI should be decided by the corresponding economic weights of the different markets considered. But the information availability of such weights on a comparable basis for all the countries considered in this study was not found (Balakrishnan et al. 2009). Therefore the variance-equal weighting method has been used as it is the next best alternative weighting method which fits well with the economic fundamentals in this literature (Illing and Liu 2006).

\[ EM_{FSI} = \beta + \text{Stock Market Returns} + \text{Stock Market Volatility} + \text{Sovereign Debt Spread} + \text{EMPI} \] (1)

The scaling of the EM_FSI is as follows; a value of zero indicates a neutral financial crisis condition, a value of 1 indicates a stress which is one standard deviation above from average conditions and any value higher than 1.5 is a severe crisis condition. A negative value indicates a stress below the neutral financial conditions. The same scaling system can be applied for the sub-indexes.
3.1.1. The Banking Sector

The Capital Asset Pricing Model beta “$$\beta$$” is used as the banking sector beta.

$$\beta_{lt} = \frac{COV (r_{t,t}^M, r_{t,t}^B)}{\sigma_{t,M}^2}$$ (2)

Where ‘$$r$$’ is the year over year banking returns and has been calculated over 12 month rolling window. ‘$$r_{t,t}^M$$’ stands for the market return rate, ‘$$r_{t,t}^B$$’ stands for the return rate of the capital assets and $$\sigma_{t,M}^2$$ stands for the variance in the market return rates. Similar to CAPM literature, $$\beta > 1$$ indicates a more than proportionate change in banking shocks to the overall stock market fluctuations. Therefore $$\beta > 1$$ means a higher volatility in the banking sector. To better identify the banking related stress, $$\beta$$ was presented only when the overall market returns were higher than the banking returns. Therefore any $$\beta > 1$$ indicates a risky banking sector (Balakrishnan et al. 2009).

3.1.2. The Security Markets Sector

The year on year change in the stock index has been multiplied by minus one to obtain the Stock market return. Therefore a decline in the equity prices indicates an increased securities market based related stress. The time varying measure of the market volatility, the stock market volatility, was derived through a GARCH (1,1) model using month to month real returns. The sovereign debt spread which is the bond yield minus the 10 year United States Treasury spread was obtained via JP Morgan EMBI Global Spreads (Balakrishnan et al. 2009).

3.1.3. Foreign Exchange Market Sector

The decline in the international reserves and the exchange rate depreciations were identified via the EMPI. This is defined for a given country $$i$$ in a given month $$t$$ as follows;

$$EMPI_{it} = \frac{(\Delta e_{lt} - \mu_{i,\Delta e})}{\sigma_{i,\Delta e}} - \frac{(\Delta RES_{i,t} - \mu_{i,\Delta RES})}{\sigma_{i,\Delta RES}}$$ (3)
In the above equation, \( \Delta e \) stands for month to month exchange rate changes (Levy Yeyati and Sturzenegger 2005) and \( \Delta RES \) stands for total reserves minus gold. The mean and the standard deviation of a given data series were presented using \( \mu \) and \( \sigma \) respectively. The effects of the hyperinflation have been correctly addressed in this equation by amending means and standard deviations for periods with and without the prevalence of hyperinflation (Balakrishnan et al. 2009). The EM-FSI was initially calculated for 26 emerging markets from 1997 to latest data available and is available with the Balakrishnan et al.’s paper “The Transmission of Financial Stress from Advanced to emerging Economies”.

4. METHODOLOGY

In the past literature, various models, including New Keynesian Dynamic Stochastic General Equilibrium models (NK DSGE), have been used to measure the impact of the financial stress on the monetary policy settings in developed countries like US, UK and Euro Area (Adjemian, Paries and Moyen 2007, Christiano 2010). But the inclusion of the financial stress variable to the model was controversial (Baxa, Vasicek and Horvath 2012). Bernanke introduced the financial accelerator mechanism to include the financial frictions to the DSGE models, which later got criticized as it only addresses one of the many financial frictions (Bernanke 1996 and 1999, Tovar 2009). It is also discussed that the NK DSGE models do not represent the entire behavior of the financial crisis effect in the monetary policy settings as they anonymously react to the heterogeneity, liquidity, and endogeneity of a financial crisis (Goodhart et al. 2009). But Baxa, Hovarth and Vasicek (2012) introduced a new way of assessing the effect of the financial stress on the monetary policy settings by modifying the forward looking monetary policy rule because of ability it has to capture the financial stress effects on the monetary policy without any information loss. Further the forward looking monetary policy rule as an ideal way to detect what a central bank is doing under given economic conditions such as recessions, financial crises, debt crises (Clarida et al. 2000). I modify the forward looking monetary policy rule by assuming the nominal interest rate and later the M2 growth rate as the key monetary policy instruments for the BRIC countries. This paper closely follows the methodology described by Kim and Nelson in 2004.
Consider the following Forward looking Taylor rule.

\[ r_t^* = \bar{r} + \beta (E[\pi_{t+i} | \Omega_t] - \pi_{t+i}^*) + \gamma E[y_{t+j} | \Omega_t] \]  

(4)

where \( r_t^* \) represents the target interest rate, the policy neutral rate \( \bar{r} \) is the sum of the real equilibrium rate and the expected inflation, \( \pi_{t+i} \) is the forecasted yearly inflation rate, \( \Omega_t \) represent the current information set, on the interest rate decisions, \( \pi_{t+i}^* \) is the central bank’s targeted inflation rate and \( y_{t+j} \) is the output gap. In practice central banks tend to reflect the effect of the market forces on the policy rates by introducing a smoothing technique to the existing policy monetary policy rule. This has been done by introducing a smoothing parameter and a random error term to the equation 4 above (Kim and Nelson 2004). The smoothing modification is as follows.

\[ r_t = \rho r_{t-1} + (1 - \rho) r_t^* + \nu_t \]  

(5)

Where \( \rho \) is the smoothing parameter \((0 \leq \rho < 1)\), \( r_t \) is interest rate at time \( t \), \( r_{t-1} \) is the one lagged period interest rate and \( \nu_t \) is a random disturbance term. By combining Equation 4 to Equation 5, the modified forward looking monetary policy rule can be written as follows. Since the inflation is highly persistence many authors including Taylor, have considered the following relationship; \( E[\pi_{t+i} | \Omega_t] - \pi_{t+i}^* = (\pi_{t+i} - \pi_{t+i}^*) \) (Fan et al. 2010, Baxa, Horvath and Vasicek 2012). Therefore the Expectation sign is excluded in equation 6.

\[ r_t = (1 - \rho)\left[ \alpha + \beta (\pi_{t+i} - \pi_{t+i}^*) + \gamma y_{t+j} \right] + \rho r_{t-1} + \varepsilon_t \]  

(6)

The forward looking monetary policy rule is used to identify how a central bank responds to a financial stress (Bulir and Cihak 2008, Fan et al 2010, Baxa, Horvarth and Vasicek 2012). Following their contribution, I introduce the financial stress index variable to the forward looking monetary policy rule in equation 7 as follows.

\[ r_t = (1 - \rho)\left[ \alpha + \beta (\pi_{t+i} - \pi_{t+i}^*) + \gamma y_{t+j} \right] + \rho r_{t-1} + \delta x_{t+k} + \varepsilon_t \]  

(7)
Where $\alpha$ is the long run nominal rate which now replace the earlier term $\bar{r}$, $x_{t+k}$ is the financial stress index and $k$ for time lags. Generally the financial stress does not directly influence the target interest rate decisions of a central bank but it can explain the reasoning behind the deviations of the actual interest rate from its target value. Therefore it has been placed outside the brackets of the above equation. The error term is a combination of all the forecasted errors in this model. The $\delta$ is the representative parameter for the financial stress and it shows a positive relationship with the financial stress variable. While these kind of time invariant forward looking monetary policy rules provide useful interpretations in explaining monetary policies for different countries, recent literature has shown the usefulness of time varying evaluations on delivering better explanations (Demers and Rodriguez 2001, Sims and Zha 2006). This concept has also been verified by Clarida et al., by indicating the usefulness of a time varying policy evaluation to describe the significant differences between the time invariant Taylor rule estimations before and after the Volker disinflation period in the U.S. economy (Clarida et al. 2000). One main reason for using time varying policy rule is the persistency in the inflation. In general, an economy can face high levels of inflation and low levels of inflation for longer time periods. This may result the target inflation rate to be changed over time. Also these two inflation levels, each last relatively for a longer period of time can result different coefficient values for the inflation gap. If this is analyzed by a time invariant model, then the coefficients may represent an average effect. But time variant models can become more informative by differentiating the behavior of the inflation gap effect on the monetary policy during two different inflation levels. Further the inclusion of the financial stress, a high volatile variable, can change the pace of the effects of other explanatory variables on the monetary policy conduct frequently. In this situation, a time invariant model does not deliver the most efficient and effective interpretations about the monetary policy conduct as it does not have the ability to capture the insights of a changing environment. The frequent regime shifts also continuously change the nature of the monetary policy conduct (Baxa, Horvath and Vasicek 2012). These highlight the importance of a time varying monetary policy rule for higher clarity in the decision making. The literature provides different time varying coefficient models such as Markov Chain Monte Carlo (MCMC), State Space

The following state space representation of a forward looking monetary policy rule is used. The forward looking monetary policy with real time variables such as financial stress creates endogeneity in the model as it tends to correlate with the error term (Kim and Nelson 2004, Baxa 2010). Moreover in a Taylor rule, both the output gap and the inflation gap determine the target interest rate. The same interest rate again influences the output gap and the inflation gap in the next period. This circular effect between dependent and independent variables also creates endogeneity in the model. This endogeneity problem must be solved to obtain valid estimations. Therefore the following state space representation is used as described by Kim and Nelson in 2004.

\[
\begin{align*}
    r_t &= (1 - \rho_t) \left[ \alpha_t + \beta_t (\pi_{t+i} - \pi_{t+i}^*) + \gamma_t y_{t+j} \right] + \rho_r r_{t-1} + \delta_t x_{t+k} + \epsilon_t \tag{8} \\
    \alpha_t &= \alpha_{t-1} + \tau_{1,t}, \tau_{1,t} \sim i.i.d. N(0, \sigma_{\tau_1}^2) \tag{9} \\
    \beta_t &= \beta_{t-1} + \tau_{2,t}, \tau_{2,t} \sim i.i.d. N(0, \sigma_{\tau_2}^2) \tag{10} \\
    \gamma_t &= \gamma_{t-1} + \tau_{3,t}, \tau_{3,t} \sim i.i.d. N(0, \sigma_{\tau_3}^2) \tag{11} \\
    \rho_t &= \rho_{t-1} + \tau_{4,t}, \tau_{4,t} \sim i.i.d. N(0, \sigma_{\tau_4}^2) \tag{12} \\
    \delta_t &= \delta_{t-1} + \tau_{5,t}, \tau_{5,t} \sim i.i.d. N(0, \sigma_{\tau_5}^2) \tag{13} \\
    \pi_{t+i} &= Z_{t-f}^i \psi + \sigma_\varphi \varphi_t, \varphi_t \sim i.i.d. N(0,1) \tag{14} \\
    y_{t+i} &= Z_{t-f}^i \Gamma + \sigma_\zeta \zeta_t, \zeta_t \sim i.i.d. N(0,1) \tag{15} \\
    x_{t+i} &= Z_{t-f}^i \eta + \sigma_\theta \theta_t, \theta_t \sim i.i.d. N(0,1) \tag{16}
\end{align*}
\]

The error terms behavior is assumed to be \([\epsilon_t \mid \Omega_{t-1}] \sim N(0, \sigma_{\epsilon_t}^2)\). Equations (9) to (13) represent the time varying coefficients as random walk processes. The equations (14) to (16) are introduced with some instrumental variables ‘Z’ to eliminate the endogeneity in the original model setting. These instrumental variables may enter to the state space model either in time varying or in time in-varying coefficients format (Kim and Nelson 2004). However this paper considers a time in-varying coefficients for instrumental variables. Following variables are chosen as instrumental
variables; The first four lags of $\pi_t, y_t$, the policy variable and the three month LIBOR at time $t$. A Heckman Type two step Maximum likelihood estimation procedure is used to eliminate the endogeneity in equation 8. For a simple example, assume that $i = 1$. The $\pi_{t,1}, g_{t,1}$ and $x_{t,1}$ variables are decomposed into two components as predicted component and the prediction error component.

$$
\begin{pmatrix}
\pi_{t,1} \\
g_{t,1} \\
x_{t,1}
\end{pmatrix}
E
\begin{pmatrix}
\pi_{t,1} \\
g_{t,1} \\
x_{t,1}
\end{pmatrix}
\Omega_{t-1}^{-1}
\end{pmatrix} +
\begin{pmatrix}
\varphi_{t|t-1} \\
\zeta_{t|t-1} \\
\theta_{t|t-1}
\end{pmatrix}
(i)

\begin{pmatrix}
\varphi_{t|t-1} \\
\zeta_{t|t-1} \\
\theta_{t|t-1}
\end{pmatrix}
= 
\left[ \begin{array}{c}
\psi_{t|t-1}^{1/2} \\

\varphi_{t|t-1}^{-1/2} \\

\zeta_{t|t-1}^{-1/2}
\end{array} \right]
\left[ \begin{array}{c}
\varphi_{t|t-1} \\
\zeta_{t|t-1} \\
\theta_{t|t-1}
\end{array} \right]
\sim i i d N
\left( \begin{array}{c}
0 \\
0 \\
0
\end{array} \right),
\left( \begin{array}{ccc}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{array} \right)
(ii)

Where $\Omega_{t-1}$ is the information set up to time $t-1$, $\Psi_{t|t-1}^{1/2}$ is the time varying conditional variance covariance matrix for a 3*1 vector prediction errors; $\alpha_{\varphi_{t|t-1}} = [\varphi_{t|t-1} - 1 \quad \zeta_{t|t-1} - 1 \quad \theta_{t|t-1}]$. $\Psi_{t|t-1}$ and $\alpha_{\varphi_{t|t-1}}$ are obtained from the Kalman filter applied to equations (14) – (15). According to Kim and Nelson (2004), it is assumed to have the following covariance structure for $\alpha_{t}^{\varphi}$ and $\nu_{t}$.

$$
\left( \begin{array}{c}
\alpha_{t}^{\varphi} \\
\nu_{t}
\end{array} \right)
\sim i i d N
\left( \begin{array}{c}
0 \\
0
\end{array} \right),
\left( \begin{array}{cc}
l_{3} & \lambda_{\nu} \sigma_{\nu} \\
\lambda_{\nu} \sigma_{\nu} & \sigma_{\nu}^{2}
\end{array} \right)
(iii)

Where $\lambda = [\lambda_{\varphi,\nu} \quad \lambda_{\zeta,\nu} \quad \lambda_{\theta,\nu}]$ is a constant 3*1 correlation vector. According to Hekman (1976) and Kim and Nelson (2004), the Cholesky Decomposition of the above covariance matrix provides the following equation.

$$
\left( \begin{array}{c}
\alpha_{t}^{\varphi} \\
\nu_{t}
\end{array} \right)
= 
\left( \begin{array}{c}
l_{3} \\
\lambda_{\nu} \sigma_{\nu} \sqrt{1 - \nu_{t} \lambda_{\nu}} \sigma_{\nu}^{2}
\end{array} \right)
\left( \begin{array}{c}
\nu_{t} \\
\omega_{t}
\end{array} \right),
\left( \begin{array}{c}
\nu_{t} \\
\omega_{t}
\end{array} \right)
\sim i i d N
\left( \begin{array}{c}
0 \\
0
\end{array} \right),
\left( \begin{array}{cc}
l_{3} & 0 \\
0 & 0
\end{array} \right)
(iv)

Then the following can be obtained from the above equation

$$
\nu_{t} = x_{t+k} + \lambda_{\varphi,\nu} \sigma_{\nu} \varphi_{t}^{*} + \lambda_{\zeta,\nu} \sigma_{\nu} \zeta_{t}^{*} + \lambda_{\theta,\nu} \sigma_{\nu} \theta_{t}^{*} + \omega_{t}
(v)

$$

where $\omega_{t} \sim N(0, \left( 1 - \lambda_{\varphi,\nu}^{2} - \lambda_{\zeta,\nu}^{2} - \lambda_{\theta,\nu}^{2} \right) \sigma_{\nu}^{2})$. 
This solves the endogeneity associated with the equation 8 as \( \omega_t \) is not correlated with \( \varphi_t|_{t-1}, \zeta_t|_{t-1}, \theta_t|_{t-1} \) and also not correlated with the inflation, output gap and financial stress variables. After the Heckman Type two step Maximum likelihood estimation procedure, the new state space model can be written as follows.

\[
\begin{align*}
    r_t &= (1 - \rho_t)[\alpha_t + \beta_t(\pi_{t+i} - \pi_{t+j}) + \gamma_t y_{t+j}] + \rho_t r_{t-1} + \delta_t x_{t+k} + \lambda_{\varphi,e} \sigma_e \varphi_t^* + \lambda_{\zeta,e} \sigma_e \zeta_t^* + \lambda_{\theta,e} \sigma_e \theta_t^* + \omega_t \\
    & (17)
\end{align*}
\]

where \( \omega_t \sim N(0, [1 - \lambda_{\varphi,e}^2 - \lambda_{\zeta,e}^2 - \lambda_{\theta,e}^2] \sigma^2_e) \). The correlation between standardized residuals \( \varphi_t^*, \zeta_t^*, \theta_t^* \) and the error term \( \epsilon_t \) is \( \lambda_{\varphi,e}, \lambda_{\zeta,e} \text{ and } \lambda_{\theta,e} \). In the above representation, \( \omega_t \) is uncorrelated with \( \varphi_t^*, \zeta_t^*, \theta_t^*, \pi_{t+i}, y_{t+j} \text{ and } x_{t+k} \). As the endogeneity issue is solved in equation 17, the following steps can be used for the estimation as described in Kim and Nelson 2006.

**STEP 1:** Estimate equations (14) – (16) via maximum likelihood estimation via Kalman filter as in Harney (1992) to obtain the standardized residuals for \( \varphi_t, \zeta_t, \theta_t \). These standardized residuals are used in step 2.

**STEP 2:** Estimate equation 17 using the Maximum likelihood estimator via Kalman Filter (Kim and Nelson 2006).

Although the above two steps are commonly used in estimating state space models, the maximum likelihood estimation via Kalman filter itself has some limitations. The Kalman filter technique is required to provide with the initial values of the parameters. Therefore the final results totally depend on the accuracy of the initial values which are generally unknown. This issue is highly associated with the financial stress variable as the effects of the financial stress on the dependent variable are highly unknown and volatile. Therefore setting the initial values is impractical for the financial stress variable. Also the log likelihood function is highly nonlinear and therefore sometimes optimization algorithms are unable to minimize the negative of the log likelihood which can either fail to calculate the Hessian matrix or the observation vector covariance matrix can result to singular for the initial values given (Schlicht and Ludsteck 2006, Baxa, Horvanth and Vasicek 2012). The Varying Coefficient estimation method (VC) which is introduced by Schlicht and Ludsteck in 2006 can be used as an alternative estimation method.
because of its superiority over the usual Kalman filter maximum likelihood estimation. The VC method estimator uses an orthogonal parameterization\(^8\) instead of the kalman filter’s initial value method. Therefore VC method solves the initial value bias in the estimated results. Moreover VC method is compatible with the endogeneity correction proposed by Kim and Nelson in 2006. In addition, the VC method is statistically superior to the Kalman filtering as it uses a two sided filter whereas the kalman filter uses only one sided filter (Schilict 2006). Kalman filtering uses only past and current values but not future values to estimate the coefficients in the model. However in general, current states are correlated with the future states and provide enriched information about the current states. The VC method uses past, current and future values to estimate the coefficients in the model. A two sided filter\(^9\) has been used for this purpose. Therefore VC method can be considered as a superior computational method to the Kalman filter. Moreover the coefficient estimation is highly disappointing for the small samples. But the GMM estimator methodology used by the VC method provides better coefficient estimation results for smaller samples (Schilict 2006). Moreover one of the main practical advantages of the VC method is the availability of the software for free of charge\(^{10}\) and its easiness. All these advantages encouraged me to follow the VC method to estimate the coefficients in the step 2 mentioned above.

The VC method\(^{11}\) is a special case of a typical linear regression model. Consider the following two equations. Equation 18 represents a linear regression model with time varying coefficients.

\[
Y_t = X_t'\alpha_t + \epsilon_t
\]  

(18)

Where \(Y\) is the endogeneous variable, \(X\) is a vector of explanatory variables and \(\alpha_t\) is a vector of regression coefficients at time \(t\). \(\epsilon_t\) is the normal disturbance term with a variance of \(\sigma^2\). Moreover it is considered that the time varying coefficient changes slowly and unsystematically

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\(^8\) For More information please read the VC Method’s technical details in Appendix 4.

\(^9\) Kalman Filter calculates the coefficients by considering the data up to the current period. But the VC method uses all information for the coefficient estimation which is superior to the typical kalman method;

\[
a_{t}^{\text{Kalman}} = E\{a_{t}|(y_{1}, y_{2}, y_{3}, ..., y_{t}), (x_{1}, x_{2}, x_{3}, ..., x_{t})\} \text{ for all } t = 1,2,3, ..., T
\]

\[
a_{t}^{\text{VC}} = E\{a_{t}|(y_{1}, y_{2}, y_{3}, ..., y_{T}), (x_{1}, x_{2}, x_{3}, ..., x_{T})\} \text{ for all } t = 1,2,3, ..., T
\]

\(^{10}\) VC method software is freely available at [http://ideas.repec.org/c/lmu/muenso/684.html](http://ideas.repec.org/c/lmu/muenso/684.html)

\(^{11}\) Refer Appendix for technical information on VC Method.
over time in order to assume that the current value of the coefficient \( a_t \) equals to the yesterday’s value \( a_{t-1} \) in the following format.

\[
a_t = a_{t-1} + V_t \tag{19}
\]

where \( V_t \) is a disturbance term associated with the above representation. It is assumed that \( u_t \) and \( V_t \) are independent.

An Ordinary least squares method picks the estimates which minimize the error sum of squares in the model; \( \Sigma_{t=1}^{T} u_{t}^2 \). But the VC method selects the estimates that minimize the weighted sum of squares of the model; \( \Sigma_{t=1}^{T} u_{t}^2 + \xi_1 \Sigma_{t=1}^{T} V_{1t}^2 + \xi_2 \Sigma_{t=1}^{T} V_{2t}^2 + \xi_3 \Sigma_{t=1}^{T} V_{3t}^2 + \ldots + \xi_n \Sigma_{t=1}^{T} V_{nt}^2 \), where the coefficient weights \( \xi_1, \xi_2, \xi_3, \ldots, \xi_n \) are determined by the inverse variance ratios \( \xi_i = \sigma_i^2 / \sigma_i^2 \). This balances the fit of the model and the parameter stability (Schlicht and Ludsteck 2006, Baxa 2010). Moreover GLS estimates of a fixed coefficient regression are used as the time averages of the time varying regression coefficients; \( \frac{1}{T} \Sigma_{t=1}^{T} a_t = a_{GLS} \) (Schlicht and Ludsteck 2006). Following the same techniques as described above, the weighted sum of squares to be minimized in our model is as follows.

\[
\Sigma_{t=1}^{T} W_{t}^2 + \theta_1 \Sigma_{t=1}^{T} \tau_{1,t}^2 + \theta_2 \Sigma_{t=1}^{T} \tau_{2,t}^2 + \theta_3 \Sigma_{t=1}^{T} \tau_{3,t}^2 + \theta_4 \Sigma_{t=1}^{T} \tau_{4,t}^2 + \theta_5 \Sigma_{t=1}^{T} \tau_{5,t}^2 \tag{20}
\]

Where \( \theta_i = \sigma_i^2 / \sigma_i^2 \).

Although the Interest rate plays a crucial role in determining and controlling the monetary policy in many countries, the BRICs do not change their interest rates very frequently (Fan et al. 2010). The past literature shows that unlike in the most of the western economies, the interest rate does not clearly explain the monetary policy conditions and the changes in macroeconomic variables for China, Russia and Brazil (Esanov et al 2005, Fan et al 2010). Bank of Russia considers the monetary aggregates as its main policy instrument (Esanov et al. 2005). Bank of China also follows monetary aggregates as the main policy tools in controlling its monetary policy (Fan et al 2010). Therefore while keeping the interest rate rule analysis to prove the poor performances of the interest rate rule in the BRICs; this paper also considers a monetary aggregate as the main policy tool.
In 2000, Bennett T. McCallum introduced a monetary aggregate policy rule to estimate the behavior of a central bank. The original McCallum rule is as follows.

\[ \Delta b_t = \Delta y^* - \Delta v_t + 0.5 (\Delta y^* - \Delta y_{t-1}) + u_t \]  

(21)

Where \( \Delta b_t \) is the percentage rate of change of monetary base. \( \Delta y^* \) is the target percentage rate of change of nominal GDP per year, \( \Delta v_t \) is the average quarterly increase of the velocity of monetary base over a four-year period, \( \Delta y_t \) is the percentage rate of change in Nominal GDP per year. The target value of Nominal GDP is calculated as the sum of the long run average rate of growth of real GDP and the target inflation rate (McCallum 2000, Esanov et al. 2005). This method requires discarding a large number of observations to average the velocity of money over the four year period. This statistical draw back together with the data unavailability for Monetary base and Velocity of Money demotivates the researcher using the original McCallum rule for estimation (Esanov et al. 2005). As an alternative, a modified version of a McCallum rule is used in the literature along with the hybrid target variable concept introduced by McCallum (McCallum 2000, Esanov et al. 2005, Fan et al. 2010). The modified McCallum rule is constructed by replacing the interest rate variable by the changes in the real monetary aggregate variable (Esanov et al. 2005). This modifies all the above equations by replacing the interest rate variable with a monetary policy aggregate; M2 growth rate. Therefore the modified equations are as follows.

\[ m_t^* = \bar{m} + \beta (E[\pi_{t+i} | \Omega_t] - \pi_{t+i}^*) + \gamma E[y_{t+j} | \Omega_t] \]  

(22)

where \( m_t^* \) is the M2 growth rate per month, \( \bar{m} \) is the long run equilibrium money growth rate, \( \pi_{t+i} \) is the forecasted monthly inflation rate, \( \pi_{t+i}^* \) is the target inflation rate, \( \Omega_t \) represent the current information set on the monetary policy decisions, \( \pi_{t+i}^* \) is the central bank’s targeted inflation rate and \( y_{t+j} \) is the output gap. This paper also considers the growth rate of the real money supply depends on its lagged value as an additional explanatory variable. This is similar to the interest rate smoothing concept when the interest rate acts as the monetary policy tool.

\[ m_t = \rho m_{t-1} + (1 - \rho)m_t^* + \nu_t \]  

(23)
Where $\rho$ is the smoothing parameter and $\nu_t$ is the random error term. By substituting equation (23) in equation (22), we get the following equation.

\[
m_t = (1 - \rho) \left[ \alpha + \beta \left( \pi_{t+i} - \pi_{t+i}^* \right) + \gamma y_{t+j} \right] + \rho m_{t-1} + \varepsilon_t
\] (24)

After including the financial stress ($x_{t+k}$), the time varying coefficient forward looking policy rule looks like follows.

\[
m_t = (1 - \rho_t) \left[ \alpha_t + \beta_t \left( \pi_{t+i} - \pi_{t+i}^* \right) + \gamma_t y_{t+j} \right] + \rho_t m_{t-1} + \delta_t x_{t+k} + \varepsilon_t
\] (25)

Following the same endogeneity correction as described above, the state space representation of equation (24) is as follows.

\[
m_t = (1 - \rho_t) \left[ \alpha_t + \beta_t \left( \pi_{t+i} - \pi_{t+i}^* \right) + \gamma_t y_{t+j} \right] + \rho_t m_{t-1} + \delta_t x_{t+k} + \lambda_{\theta,\varepsilon} \sigma_{\varepsilon} \phi_t^* + \lambda_{\varepsilon,\varepsilon} \sigma_{\varepsilon} \zeta_t^* + \lambda_{\theta,\varepsilon} \sigma_{\varepsilon} \theta_t^* + \omega_t
\] (26)

The notations for all the other common variables and coefficients are similar to the interest rate rule described above. A stabilizing rule for the M2 growth is counter cyclical to that of interest rate rule. Therefore unlike the interest rate coefficient values, the money growth rate coefficients take the following values, $\beta_t < 0$ and $\gamma_t < 0$ (Kong and Kamoike 2006, Fan et al. 2010). Unlike in the interest rate rule, the first lag of the M2 growth rate can be added to the policy rule because of the following reasons. Although the central bank has the ability to define and control the interest rate precisely, it does not have a hundred percent control on the M2 growth rate as the money growth rate highly fluctuates to the changes in inflation and the market demand (Fan et al 2010). Therefore unlike in the interest rate rule, the smoothing parameter $\rho_t$ in the money growth rule cannot be defined as a priori.

In general, small open economies may consider some additional variables in their monetary policy settings. Exchange rate is one of the commonly used variables in both modified versions of Taylor rule and the McCallum rule (Baxa 2010, Fan et al. 2010). Since the exchange rate is a determining factor of the policy variable, it is added inside the parenthesis in the following equation.

\[
m_t = (1 - \rho_t) \left[ \alpha_t + \beta_t \left( \pi_{t+i} - \pi_{t+i}^* \right) + \gamma_t E_{t} + \phi_t E_t \right] + \rho_t m_{t-1} + \delta_t x_{t+k} + \lambda_{\theta,\varepsilon} \sigma_{\varepsilon} \phi_t^* + \lambda_{\varepsilon,\varepsilon} \sigma_{\varepsilon} \zeta_t^* + \lambda_{\theta,\varepsilon} \sigma_{\varepsilon} \theta_t^* + \omega_t
\] (27)

where $E_t$ is the current period real effective exchange rate. The above procedure is used to analyze the effects of the financial stress on the monetary policy settings in BRICs.
In general, when Central Banks make decisions, they consider 4-8 quarters ahead target horizons. But the literature in this field suggests 2 quarters ahead target horizons for the central banks (Baitini and Nelson 2001, Kim and Nelson 2004, 2006, Baxa 2010, Fan et al. 2010). However this paper assumes that the central banks in BRICs consider only one quarter ahead target horizon. Since I use monthly data, it is assumed that \( i=3 \) in the above equations. A typical Taylor rule considers the current period output gap in the estimation process. But this paper uses one month lagged output gap (i.e. \( j = -1 \)) because of the following reasons; The Hodrick Prescott filter statistical method is used to calculate the output gap, a calculation and an approximation error can be detected in the results. Moreover the Industrial Production Index has been used for the output gap calculations as the Gross Domestic product data is not available in monthly frequency. This creates a data approximation error. Moreover the inclusion of the future output gap values in the forward looking monetary policy rule may create a forecasting error in the model. However the past output gap values may not create any forecast errors in the model. Therefore the one month lagged output gap has been considered to minimize the external errors associated with the data.

A composite index for banking stress, security market stress and exchange market stress can be obtained by adding the relevant sub-components of each market segment in the financial stress (Balakrishnan et al. in 2009, Baxa, Hovanth and Vasicek 2012). Since the components of the three market segments are calculated individually, these sub stress indexes can be considered to be independent of each other. The banking beta is used to represent the banking stress. The security market stress has been represented by the summation of the stock market returns, stock market volatility and sovereign debt spreads. The exchange market stress is represented by EMPI. The same model can be used for these three main components of the financial stress; banking stress, Stock market Stress and Exchange Market Stress in three different steps to identify the relationship between the instability in these three markets on the monetary policy setting in BRICs. These three sub stress components will enter to the state space model through \( x_{t+k} \).
5. DATA

I use monthly observations on macroeconomics variables in this study. India has been dropped from the study as it does not have proper data for financial stress and M2 for a considerable period of time. Moreover the considered sample periods are different from country to country because of the limited data availability. Following sample periods are considered; 2000 January to December 2009 for Brazil, 1997 December to 2009 December for Russia and 1997 March to 2009 December for China.

Unlike the western countries, BRIC countries hardly change their interest rates with the time. Especially China sometimes maintains the same interest rate for more than one years’ time period. This creates a significant data non-volatility issue as this study concerns with monthly data. Therefore the following data modifications were carried out for better results. The official interest rate, $r_t$, for China has been calculated as an average of 1 year commercial lending rate and 1 year deposit rate. This average value fluctuates frequently over time and also highly correlates with official bank rate of China. Therefore it can be considered as a proper substitute for the official interest rates for China. This measure may not be exact as the official bank rate but the values are closer to each other. Therefore it is considered as a proper alternative for the official rate. The Refinancing rate is used as the interest rate policy variable for Russia. The discount rate is used for Brazil. The M2 growth rate which is calculated as the month on month change is considered as the monetary aggregate policy variable. Inflation is calculates as the month on month change in the Consumer Price Index (CPI) for Russia and China. Since Brazil is an inflation targeting country, we need to consider the target inflation in our forward looking monetary policy. However the target inflation is in annual percentage levels. So a month on month CPI change is irrelevant. So I calculate the future inflation rate by comparing the 3 months ahead CPI values with its 12 month lagged CPI values. The main data issue was obtaining monthly data for the output gap. Since the Gross Domestic Product (GDP) is not available in monthly frequency, it is required to use the Industrial Production Index for the Output gap calculations.

12 International Monetary Fund’s (IMF) International Financial Statistics (IFS) data (2011 release), FRED data and Balakrishnan’s IMF web page are used to obtain data for this study.
which creates data approximation errors and calculation errors in the result. The Hodrick Prescott filter with 14400\textsuperscript{13} smoothing parameter is used to calculate the output gap (Hodrick Prescott 1997). The real effective exchange rate (REER) from IMF’s International Financial Statistics data is used as the exchange rate. The following modification has been done to make the REER more meaningful in the analysis; 

\[ E_t = 100 \times \frac{\log(\text{REER}_t)}{100} \]

The Emerging Market Financial Stress Index (EM-FSI) is used to measure the financial instability in BRICs. EM_FSI is available in monthly frequency for Brazil, Russia and China for a considerable period of time (Balakrishnan et al. 2009)\textsuperscript{14}. The sub components of the financial stress; the Banking stress, Security market related stress and the Foreign exchange market related sub index are also collected from the paper “The Transmission of Financial Stress from Advanced to Emerging Economies” Balakrishnan (2009). Figure 2 shows the variations of EM-FSI for the BRIC countries. Brazil, Russian Federation and China have sufficient EM-FSI data for an analysis but India is dropped from the analysis as it does not have enough EM-FSI data series for an analysis.

\textbf{Figure 2:} IMF Financial Stress Indicator for the BRIC countries; Brazil, Russia and China. A higher value indicates a higher stress (Balakrishnan et al. 2009). India is dropped from this series as it does not have enough data for EM_FSI.

\textsuperscript{13} Hodrick Prescott filter provides 14400 as the smoothing parameter for Monthly data. Appropriate Hodrick Prescott filter smoothing parameter values depend on the periodicity of the data; Yearly — 100, Quarterly — 1600 and Monthly — 14400.

\textsuperscript{14} A Big thank goes to Dr. Balakrishnan for sharing the EM_FSI data.
A positive value indicates a higher financial stress and negative values indicate a lower financial stress with compared to the long run financial stress in the economy. Stress Indexes close to zero indicate a neutral financial stress conditions in the economy.

**6. RESULTS**

The first analysis describes the effects of financial stress on monetary policy setting given the interest rate as the primary monetary policy rule. This model does not provide reliable results on the monetary policy of the BRICs as their interest rate does not fluctuate frequently in monthly data. The results are presented in figure 3 to justify that statement. Therefore M2 growth rate has been considered as the key policy variable for the BRICs. The results of this analysis are also presented in this section. BRIC countries are considered as small open economies in the world. Therefore the exchange rate is considered as an influencing variable for their monetary policy. Therefore the results for the monetary policy given the exchange rate as an influencing variable in policy setting have also been presented in this section. The time varying coefficients of the variables are also be discussed.

**6.1 The Time varying Effects of Financial stress on Interest Rate Rule Monetary Policy**

This section describes the time varying effects of financial stress on the interest rate rule. According to figure 3, the effect of the financial stress variable on the interest rate rule is considerably higher during unstable economic conditions in the BRICs. However the effects of
the financial stress on interest rate rule in regular economic times are negligible. The effect of financial stress on interest rate setting is considerably positive during major economic instability periods in Brazil; 1998-1999 Brazilian Currency Crisis, 2002 South American Economic Crisis and 2008 Global Financial Crisis. The financial stress during 1998-1999 Currency crisis seems to have higher effects on interest rate setting than that during the recent 2008 financial crisis. However in good economic times, the effects of the financial stress on interest rate rule are negligible. Russia has experienced couple of financial and economic crises throughout its history; The 1998 Russian financial crisis and the 2008 Global Financial crisis. According to figure 3, the effects of the financial stress on the interest rate rule is considerably higher for Russia during those two crises. As in Brazil, in normal economic times the effects of financial crisis on the interest rate rule are almost zero.

In general, when an economy faces a financial crisis the central bank reduces its interest rates to control the crisis. According to this rational, the effects of the financial stress on interest rate rule should be negative (Baxa, Horvath and Vasicek 2012). But Brazil and Russia show the opposite. However China seems to follows this rational. According to figure 3, the effects of the financial stress on the interest rate rule for China seems to be considerably higher during the late 1997 Asian Financial Crisis and 2008 Global Financial Crisis. Moreover during these financial crises, China shows higher negative effects on the interest rate settings. Unlike in other two countries, Chinese interest rate rule is positively influenced by the financial stress variable during normal economic times; from mid-2002 to late-2007. Out of the three countries, the magnitude of the effect of financial stress on interest rate setting is considerably higher in Russia. Although figure 3 provides an idea about the effects of the financial stress on interest rate settings, its significance in the model can be identified through the time varying coefficient values for financial stress in figures 10, 11 and 12. For Brazil, the financial stress coefficients vary over time. The significance of the financial stress on monetary policy setting is insignificant at 10% significance level during most times for Brazil. However the financial stress coefficient gets

15 Speech by Chairman Ben S. Bernanke; At the Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming, August 31, 2012; http://www.federalreserve.gov/newsevents/speech/bernanke20120831a.htm
significant at 10% significant level during the peak times of 1998-1999 Brazilian Currency crisis, 2002 South American Economic Crisis and 2008 Global Financial crisis. Although the financial stress coefficients in interest rate rule monetary policy setting in China and Russia are significant at 10% significant level for the entire time period considered, the values do not fluctuate. Despite some minor changes in the coefficient values during strong financial crisis times, figure 11 and 12 indicate almost constant financial stress coefficients for both China and Russian Federation through out the time periods considered.

As previously mentioned, the Peoples Bank of China, the Central Bank of Russia mainly follows monetary aggregates in their monetary policy settings (Esanov et al. 2005, Fan et al. 2010). Since the interest rate rule results were in unsatisfactory levels, I assume that the Central Bank of Brazil also considers a monetary aggregate in their policy settings. Following results describe the effects of financial stress on monetary policy settings in BRICs considering the M2 growth rate as the main monetary policy tool. According to figure 4, the effect of financial stress on the monetary policy variable is significantly higher during the economic and financial crisis times in all three countries. For Brazil, it is clearly evident that the effects of financial stress on monetary policy settings were considerably higher during 1998-1999 Currency Crisis, 2002 South American Economic Crisis and 2008 global financial crisis. These positive effects indicate that the higher financial stress periods encourage the central Bank of Brazil to increase the money supply. Especially the results indicate that the central bank in Brazil provided more attention on the financial stress during the 2002 South American Economic crisis time. The effect of financial stress on monetary policy during 2008 global financial crisis was not significant as much as the other two previous stress periods. This indicates that the Brazilian central bank was more concerned about the regional crises than the global financial stresses come from the advanced country economies. The Central bank of Russia was more concern about the financial stress in their monetary policy settings during the 1998 Russian Financial crisis. During that time the financial stress increased the M2 growth. During normal economic times the effect of the financial stress on the monetary policy setting is negligible.
Figure 3: The effect of Financial Stress on Interest Rate Rule Monetary policy

Note: These figures show the magnitude of the financial stress effect on the interest rate rule monetary policy setting. The $y$-axis is defined as the product of the IMF financial stress indicator and the estimated coefficient on the financial stress indicator in the model ($\delta x$).
However the financial stress effect on the Russian monetary policy during 2008 global financial crisis was lower than that during 1998 Russian Financial Crisis. As in Brazil, this again proves that the BRIC countries are more concerned about the regional financial crises than the stresses come from the advanced country financial crises. The effect of financial stress on monetary policy rule in China is considerably higher during the aftermath of the 1997 Asian Financial crisis. During this period the financial stress positively influenced the money growth rate. However the effects of financial stress on the monetary policy rule were negative during the early months of the 2008 global financial crisis. But from early 2009, the effects of the financial crisis on the monetary policy settings were positive. These indicate that China was more concerned about the regional financial stress than the global financial stress.

Although the above results indicate that the financial stress influences the money growth, to validate the results it is required to check the significance of the coefficients. The time varying coefficient estimations of the financial stress for Brazil and Russia respectively in figure 10 and figure 14 indicate that the financial stress coefficients are not significant at 10% significant level during the considered time period. However the time varying coefficients of financial stress are significant at 10% significant level during the 1997 Asian financial crisis for China. Moreover the 2008 financial stress was not a significant influencing factor on the monetary policy settings for China at 10% significant level.

When the exchange rate is introduced to the monetary policy rule (Figure 5), the magnitude of the financial stress effect on the monetary policy got weakened in Brazil and Russia. However for China, the inclusion of the exchange rate did not reduce the financial stress effect on the monetary policy rule compared to the model without the exchange rate. Despite those changes all the other results were the same for all three countries in the monetary policy rule with exchange rate.
Figure 4: The Effect of Financial Stress on Monetary Policy Setting (M2 Growth Rate as the Policy tool)

[Brazil Graph]

Russia Graph

China Graph

Note: These figures show the effect of financial stress on the interest rate rule monetary policy setting. The y-axis is defined as the product of the financial stress indicator and the estimated coefficient on the financial stress indicator in the monetary policy settings (δx)
Figure 5: The Effect of Financial Stress on Monetary Policy Setting given the Real effective Exchange rate as an additional explanatory variable and the M2 growth rate as the primary policy tool.

Note: These figures show the effect of financial stress on the interest rate rule monetary policy setting. The y-axis is defined as the product of the financial stress indicator and the estimated coefficient on the financial stress indicator in the monetary policy settings (δx).
The Financial stress is measured as the sum of banking stress, security market stress and the exchange rate stress. This classification is used to analyze the effect of banking stress, security market stress and exchange market stress on the monetary policy settings in BRICs. The literature shows that the advanced countries like US and UK respond to banking and stock market stress than that for the exchange market stress (Baxa, Horvarth and Vasicek 2012). The figure 6 shows the effect of these three stresses on the monetary policy setting given the M2 growth rate is the policy tool. Figure 7 shows the effects of the three sub stress indexes on the same monetary policy given the exchange rate is in the model.

According to figure 6, the exchange rate stress seems to be the most influencing sub stress on the monetary policy settings in the BRICs. Since the BRICs being open economies, they are highly influenced by the exchange rate and other open market operations. The financial issues in advanced countries can easily transmitted to BRICs countries though the exchange rate avenue as they are highly connected with advanced countries through exports, imports and foreign remittances (Balakrishanan et al. 2009). However, the effects of banking and security market stress on the monetary policy settings in BRICs are at minimum as these countries do not have strong banking and security market connections with the advanced countries (Molano 2009, Balakrishanan et al. 2009). For Russia, the exchange rate stress negatively influenced the M2 growth rate during the 1998 Russian Financial Crisis and the 2008 global financial crisis. However this effect during the 1998 Russian financial crisis was much higher than that during 2008 global financial crisis. The banking stress effect was prominent during the 2008 global financial crisis. This indicates how the banking and asset market collapses in western countries influenced the Russian Federation during the 2008 financial crisis time. During the normal economic conditions the effects of sub stress indexes on the monetary policy settings were negligible for Russia. The Chinese monetary policy was highly influenced by the exchange rate stress during the 1997 Asian financial crisis and the 2008 global financial crisis. It is clearly seen from figure 6 that the exchange rate stress was prominent even after the 1997 Asian Financial Crisis. Also the Chinese monetary policy makers seem to consider the banking stress in their monetary policy settings during the latter periods of the 1997 Asian Financial crisis.
The Brazilian monetary policy makers were more influenced by the banking stress during the 2008 global financial crisis. The exchange rate stress also positively influenced the M2 growth rate during that time. During mid-2000s the effect of exchange rate stress on the monetary policy was negative and this indicates its influence on a reduction in the money supply. The effect of the security market stress is prominent during the 2002 South American Economic crisis and its positive effects on increasing the M2 growth. Despite those changes the effects of the three sub financial stress indexes were negligible during other periods.

When the exchange rate is included in the policy rule as an additional explanatory variable, none of the above observations were changed\textsuperscript{16}. However the intensity of the effects were slightly reduced compared to the policy model without the exchange rate. So these results prove that the BRICs are more concerned about the exchange rate stress in their monetary policy settings than the banking and the security market stresses. Moreover the effects were more intense during the local economic downturns than the 2008 Global financial crisis. Figures 8 and 9 provide a separate graphical representation of the sub-indexes effects on monetary policy for each country. It is also observable from the figures 3 to 8, that the effects of the sub financial stresses do not necessarily add up to the effect of the entire financial stress. In some situations the positive effects cancels out the negative effects to neutralize the total stress effect during normal economic times.

\textsuperscript{16} See Figure 6
Figure 6: Effect of All Three Sub Indexes on the Monetary Policy Rule (M2 Growth rate as the Primary Policy tool)

Note: These figures show the effect of different financial stresses on the monetary policy setting. The y-axis is defined as the product of the financial stress indicator and the estimated coefficient on the financial stress indicator in the monetary policy settings (δx)
Figure 7: Effect of All Three Sub Indexes on Monetary Policy Rule Given Exchange Rate in the Policy (and M2 Growth rate as the Policy tool)

Note: These figures show the effect of different financial stresses on the monetary policy setting. The y-axis is defined as the product of the financial stress indicator and the estimated coefficient on the financial stress indicator in the monetary policy settings (δx)
Figure 8: Effect of All Three Sub Indexes on Monetary Policy Rule (M2 Growth rate as the Policy tool)

- **BRAZIL**

1. **Exchange Rate Stress**
   - Y-axis: -2 to 2.5
   - X-axis: 1997 to 2009

2. **Security market Stress**
   - Y-axis: -2 to 2.5
   - X-axis: 1997 to 2009

3. **Banking Stress**
   - Y-axis: -2 to 2.5
   - X-axis: 1997 to 2009
RUSSIA

Exchange Rate Stress

Security Market Stress

Banking Stress
Note: These figures show the effect of different financial stresses on the monetary policy setting. The y-axis is defined as the product of the financial stress indicator and the estimated coefficient on the financial stress indicator in the monetary policy settings (δx).
Figure 9: Effect of All Three Sub Indexes on Monetary Policy Rule given Exchange Rate in the model (M2 Growth rate as the Policy tool)

**BRAZIL**
Note: These figures show the effect of different financial stresses on the monetary policy setting. The y-axis is defined as the product of the financial stress indicator and the estimated coefficient on the financial stress indicator in the monetary policy settings ($\delta x$)
6.2. The Time Varying Policy Estimates of the Monetary Policy

The literature has already identified the possible values for the optimal taylor rule policy for both western and non western countries (Taylor 1993, Kim and Nelsom 2006, Nelson 2008, Fan et al. 2010). According to the original taylor rule developed by John Taylor for the United States Federal Reserve Bank, the inflation was given a coefficient value of 1.5 while the output gap was given a value of 0.5. But these values were revised and revisited by many other macroeconomists and suggested that there can be some slight changes to these values depending on the model, variables and the time period a researcher considers with (Kong and Kamoike 2006). However the inflation coefficients always tend to provide positive values close to 1 for the western and advanced economies. But in general, the inflation coefficients in small open economies like China, Brazil and India show positive values which ranges between 0.4 and 1 (Fan et al. 2006, Kong and Kamiike 2006). They have identified that the taylor rule coefficients for non western countries do not take higher values as those for the western countries. Moreover the output gap coefficients have shown wide range of values for the non western countries (Esanov et al. 2005, Fan et al. 2006). However the interest rate smoothing coefficient has shown positive values close to 1 for both western and non western countries (Fan et al. 2006, Baxa, Horvarth and Vasicek 2012).

This paper considers three forms of monetary policy modifications; the forward looking interest rate rule monetary policy, the forward looking M2 growth rate monetary policy and the forward looking M2 growth rate monetary policy given the exchange rate as an additional explanatory variable in the model. The forward looking interest rate rule model provides following results for the coefficient estimations (figures 10 to 12). In general inflation coefficients are positive and between 0.4 and 1 for BRICs. However in this analysis, the time varying inflation coefficients for Brazil are between -0.03 and 0.035. These values are significantly lower than the average values in the past literature. However the coefficients decrease during major economic crisis times; 1998-1999 Currency crisis, 2002 South American Economic crisis and 2008 global financial crisis. The coefficients get higher negative values during 1998-1999 Currency Crisis and 2002 South American Economic crisis. This explains that during economic crisis times the Brazilian Central Bank reduced the interest rates. Although a country with higher inflationary issues should show
higher inflation coefficients in the taylor rule, this analysis shows that the inflation coefficients are not either higher or significant. Moreover the output gap coefficients show higher fluctuations during the three crises. However the interest rate smoothing coefficients are significant at 10% significant level. The coefficient values also indicates that the interest rate smoothing plays a significant role in the policy making process. The inflation coefficients are considerably higher during the 1998 Russian Financial crisis compared to those after the crisis. Moreover the inflation coefficients are significant at 10% significant level during the 1998 crisis time. However these coefficients miss represent the relationship between inflation and interest rate by assigning negative values. The output gap coefficients are significant through the entire time period considered. This indicates that the Russian monetary policy makers allocate more attention on the output gap in their policy settings. Moreover during the 1998 Russian Financial crisis, the output gap coefficients are at their highest. This proves that the Russian economy considers real economic variables in their monetary policy setting. The interest smoothing parameter is around 0.5 and it is compatible with the previous literature (Esanov et al 2006). In China, neither the inflation coefficient or the output gap coefficients are significant at 10% significant level. However the inflation coefficients take relatively higher values during the 1997 Asian financial crisis time as the People's bank of China's main objective during this time was to control the high inflation. Moreover the inflation coefficient gets higher during early 2008 indicating possible actions on controlling inflation. However the inflation coefficient is decreased during the latter periods of the 2008 financial crisis. The interest rate smoothing takes higher values during the economic crisis times. The financial stress is significant at all times in the interest rate rule setting.

Since the estimated coefficients show significantly lower values for inflation, output gap, I can conclude that the interest rate rule is not an efficient monetary policy tool for the BRICs. Therefore the same analysis is carried out by considering the M2 growth rate as the monetary policy tool. The results are shown in figures 13-15. For Brazil\textsuperscript{17}, the results show that the inflation coefficients are not significant at 10% significant levels but their values are time varying. The

\textsuperscript{17} Refer Figure 13
output gap coefficients are significant at 10% significant level. In general, when the money growth rate is considered as the primary policy tool, the inflation coefficients and the output gap coefficients should show negative values. But for Brazil, although most inflation coefficients are compatible with this condition, the output gap coefficients are not. Unfortunately, most of the inflation and output gap coefficient results for Brazil were not compatible with the economic intuition.

The inflation coefficients and the output gap coefficients significantly time varying for Russia. Most of the inflation coefficients become significant after late 2001. Moreover the inflation coefficients are negative and close to the values suggested by Esanov et al in 2005. The response of money growth rate rule to inflation gets stronger after late 2001. According to the inflation coefficient graph, the values are not significant at 10% significant level during 1998 and 1999. However the output gap coefficients are significant at 10% significant level. This indicates that Russia used real economic variables in managing the monetary policy during 1998 and 1999. The Financial stress coefficients are insignificant at 10% significant level in Russia. This suggests that Russian monetary policy makers make no concerns on the financial stress in their monetary policy process.

As a primary monetary policy, the money growth rate rule performs significantly better than the interest rate rule for China as both inflation coefficients and the output gap coefficients are significant at 10% significant level. Moreover their values are highly compatible with the previous literature where inflation coefficients around -0.60 and output gap coefficient around -0.1 (Fan et al. 2006). Both inflation coefficients and output gap coefficients are time varying. The financial stress coefficients are significant at 10% significant level at some periods during the 1997 Asian economic crisis.

\[^{18}\text{Refer Figure 14}\]
\[^{19}\text{Refer Figure 15}\]
Figure 10: Time Varying Monetary Policy Rule Estimation (Interest rate as the primary policy tool) - BRAZIL

**BRAZIL**

Inflation Coefficient ($\beta$)  
Output Gap Coefficient ($\gamma$)

Interest Rate Smoothing ($\rho$)  
Financial Stress Coefficient ($\delta$)

Note: The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover y-axis represents the coefficient values.
Figure 11: Time Varying Monetary Policy Rule Estimation (Interest rate as the primary policy tool) - RUSSIA

RUSSIA

Inflation Coefficient ($\beta$)  
Output Gap Coefficient ($\gamma$)

Interest Rate Smoothing ($\rho$)  
Financial Stress Coefficient ($\delta$)

Note: The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover y-axis represents the coefficient values.
**Figure 12**: Time Varying Monetary Policy Rule Estimation (Interest rate as the primary policy tool) - CHINA

**CHINA**

**Inflation Coefficient (β)**

**Output Gap Coefficient (γ)**

**Interest Rate Smoothing (ρ)**

**Financial Stress Coefficient (δ)**

*Note*: The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover y-axis represents the coefficient values.
Figure 13: Time Varying Monetary Policy Rule Estimation (M2 Growth rate as the primary policy tool) - BRAZIL

BRAZIL

Inflation Coefficient ($\beta$)  Output Gap Coefficient ($\gamma$)

M2 Growth rate Smoothing ($\rho$)  Financial Stress Coefficient ($\delta$)

Note: The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover y-axis represents the coefficient values.
Figure 14: Time Varying Monetary Policy Rule Estimation (M2 Growth rate as the primary policy tool) - RUSSIA

RUSSIA

Inflation Coefficient (β)       Output Gap Coefficient (γ)

Interest Rate Smoothing (ρ)    Financial Stress Coefficient (δ)

Note: The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover y-axis represents the coefficient values.
**Figure 15:** Time Varying Monetary Policy Rule Estimation (M2 Growth rate as the primary policy tool) - CHINA

**CHINA**

- **Inflation Coefficient (β)**
- **Output Gap Coefficient (γ)**
- **Interest Rate Smoothing (ρ)**
- **Financial Stress Coefficient (δ)**

**Note:** The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover, y-axis represents the coefficient values.
In Brazil, when the real effective exchange rate is introduced to the policy rule, it is evident that the output gap coefficient shows time varying behavior and its coefficients become significant at 10% significant level during late 2008. Moreover the money growth rate smoothing parameter is also significant at 10% significant level through out the entire time period considered. The effect of the real exchange rate coefficients on the money growth rate is negative during the 1998-1999 currency crisis and the 2002 South American Economic crisis. Moreover this negative relationship expands to the late 2004. However the exchange rate coefficients get positive at 10% significant level from the beginning of 2005. Especially the exchange rate coefficients are significant at 10% significant level during the 2008 financial crisis. The inclusion of exchange rate makes the policy variable coefficients lower than those in a monetary policy without the exchange rate. Russian results are almost the same in both scenarios. The exchange rate coefficients are not significant at 10% percent significant level and they have a negative effect on the money growth rate through out the entire time period considered. With the introduction of the real effective exchange rate in the monetary policy rule for China makes the output gap coefficients to be insignificant at 10% significant level. The financial stress coefficients are significant at 10% significant level during the 1997 Asian financial crisis time. Also it is highly time varying through out the entire time period considered for China. The results show that the effect of the financial stress on the monetary aggregate rule are insignificant at most times. However the financial stress coefficients are significant at 10% significant level during the 1997 Asian Financial Crisis for China. This indicates that the BRIC countries hardly responded to the 2008 financial crisis in their monetary policy settings.

In addition, a Generalized Method of Moments (GMM) procedure is used to justify the above results. However these GMM results are time invariant and therefore will not display the time varying fluctuations in the coefficients.

6.3. The generalized Method of Moments (GMM) Results

The following tables provide the results for the Generalized Method of Movements (GMM) results for Brazil, Russia and China. The monetary policy rule with M2 growth rate as the principle
policy tool is used for this analysis. The first model estimates the variable coefficients of the basic forward looking monetary policy rule. The second model estimates the variable coefficients of the forward looking monetary policy rule given the financial stress index in the model. The third model estimates the variable coefficients of the forward looking monetary policy rule given both financial stress and the real effective exchange rate variables in the model.

\[
\text{Model 1 : } m_t = (1 - \rho)[\alpha + \beta (\pi_{t+i}) + \gamma y_{t+j}] + \rho m_{t-1} + \varepsilon_t
\]

\[
\text{Model 2 : } m_t = (1 - \rho_t)[\alpha_t + \beta_t (\pi_{t+i}) + \gamma_t y_{t+j}] + \rho_t m_{t-1} + \delta_t x_{t+k} + \varepsilon_t
\]

\[
\text{Model 3 : } m_t = (1 - \rho_t)[\alpha_t + \beta_t (\pi_{t+i}) + \gamma_t y_{t+j} + \phi_t E_t] + \rho_t m_{t-1} + \delta_t x_{t+k} + \varepsilon_t
\]

Where \(i=3, j=1\) and \(k=-1\).

The GMM estimation was preceded with the help of the following instrumental variables; first twelve lags of M2 growth rate, lags of interest rate, lags of output gap, lags of financial stress index, lags of real effective exchange rate and lags of London Interbank Rate. The lag selection was a trial and error procedure and therefore different countries have different lags of the same variables in the GMM calculation. Model 1 does not use the lags of real effective exchange rate and the financial stress index. Model 2 does not use the lags of exchange rate.

**BRAZIL**

**Table 1: GMM Results for Brazil**

<table>
<thead>
<tr>
<th>Model (Brazil)</th>
<th>(\beta)</th>
<th>(\gamma)</th>
<th>(\rho)</th>
<th>(\phi)</th>
<th>(\delta)</th>
<th>(R^2)</th>
<th>Durbin Watson</th>
<th>J statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.5632* (0.0652)</td>
<td>-0.1291 (0.1723)</td>
<td>-0.0972* (0.0262)</td>
<td>-0.0972* (0.0262)</td>
<td>-3.7099</td>
<td>0.6</td>
<td>2.58</td>
<td>0.297</td>
</tr>
<tr>
<td></td>
<td>-8.638</td>
<td>-0.7493</td>
<td>-0.1291 (0.1723)</td>
<td>-0.0972* (0.0262)</td>
<td>-3.7099</td>
<td>0.6</td>
<td>2.58</td>
<td>0.297</td>
</tr>
<tr>
<td>2</td>
<td>-0.4892* (0.1286)</td>
<td>-0.1429 (0.0992)</td>
<td>-0.1082* (0.0256)</td>
<td>-0.1082* (0.0256)</td>
<td>-4.2266</td>
<td>0.64</td>
<td>2.92</td>
<td>0.312</td>
</tr>
<tr>
<td></td>
<td>-3.804</td>
<td>-1.4405</td>
<td>-0.1429 (0.0992)</td>
<td>-0.1082* (0.0256)</td>
<td>-4.2266</td>
<td>0.64</td>
<td>2.92</td>
<td>0.312</td>
</tr>
<tr>
<td>3</td>
<td>-0.4346* (0.0863)</td>
<td>0.0028 (0.0639)</td>
<td>0.1292* (0.0172)</td>
<td>-0.0281* (0.0108)</td>
<td>-0.0281* (0.0108)</td>
<td>-0.1982 (0.1382)</td>
<td>-1.4342</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>-5.0359</td>
<td>0.0438</td>
<td>0.1292* (0.0172)</td>
<td>-0.0281* (0.0108)</td>
<td>-0.0281* (0.0108)</td>
<td>-0.1982 (0.1382)</td>
<td>-1.4342</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Note: The standard error is given in brackets. The t-statistic is highlighted in Yellow. * is for significant at 5% level. ** is for significant at 10% level.
Table 2: GMM Results for Brazil

<table>
<thead>
<tr>
<th>Model</th>
<th>β</th>
<th>γ</th>
<th>ρ</th>
<th>φ</th>
<th>δ</th>
<th>R²</th>
<th>Durbin Watson</th>
<th>J statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.5751*</td>
<td>0.0981*</td>
<td>0.1015*</td>
<td>(0.0181)</td>
<td>0.75</td>
<td>2.19</td>
<td>0.196</td>
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<tr>
<td></td>
<td>(0.0358)</td>
<td>(0.0149)</td>
<td>(0.0181)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-16.0642</td>
<td>6.5839</td>
<td>5.6077</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-0.3426*</td>
<td>-0.0561**</td>
<td>0.1920*</td>
<td>(0.0246)</td>
<td>-0.1735</td>
<td>(0.1416)</td>
<td>0.76</td>
<td>2.44</td>
</tr>
<tr>
<td></td>
<td>(0.0511)</td>
<td>(0.0334)</td>
<td>(0.0246)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-6.6993</td>
<td>-1.6796</td>
<td>7.8049</td>
<td></td>
<td>-1.2254</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-0.3333*</td>
<td>0.0173</td>
<td>0.1329*</td>
<td>(0.0149)</td>
<td>-0.0063</td>
<td>(0.0288)</td>
<td>0.66</td>
<td>2.38</td>
</tr>
<tr>
<td></td>
<td>(0.0357)</td>
<td>(0.0242)</td>
<td>(0.0149)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-9.3388</td>
<td>0.7159</td>
<td>8.9225</td>
<td>-0.2204</td>
<td>-1.0455</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The standard error is given in brackets. The t-statistic is highlighted in Yellow. * is for significant at 5% level. ** is for significant at 10% level.

Table 3: GMM Results for China

<table>
<thead>
<tr>
<th>Model</th>
<th>β</th>
<th>γ</th>
<th>ρ</th>
<th>φ</th>
<th>δ</th>
<th>R²</th>
<th>Durbin Watson</th>
<th>J statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.5147*</td>
<td>-0.0463</td>
<td>-0.1819*</td>
<td>(0.0570)</td>
<td>0.72</td>
<td>2.20</td>
<td>0.095</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0985)</td>
<td>(0.0316)</td>
<td>(0.0570)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-5.2254</td>
<td>-1.4652</td>
<td>-3.1912</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-0.5631*</td>
<td>-0.0044</td>
<td>-0.2075*</td>
<td>(0.0518)</td>
<td>-0.2032*</td>
<td>(0.0622)</td>
<td>0.76</td>
<td>2.24</td>
</tr>
<tr>
<td></td>
<td>(0.0715)</td>
<td>(0.0472)</td>
<td>(0.0518)</td>
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</tr>
<tr>
<td></td>
<td>-7.8755</td>
<td>-0.0932</td>
<td>-4.0058</td>
<td></td>
<td>3.2669</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-0.4093*</td>
<td>0.0009</td>
<td>-0.4925*</td>
<td>(0.0456)</td>
<td>-0.4069*</td>
<td>(0.1211)</td>
<td>0.76</td>
<td>1.85</td>
</tr>
<tr>
<td></td>
<td>(0.0807)</td>
<td>(0.0418)</td>
<td>(0.0456)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-5.0719</td>
<td>0.0215</td>
<td>-10.8004</td>
<td></td>
<td>-3.3600</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The standard error is given in brackets. The t-statistic is highlighted in Yellow. * is for significant at 5% level. ** is for significant at 10% level.

According to Model 1 for Russia, the M2 growth rate responded negatively to the inflation rate. Both output gap and the inflation coefficients are significant at 5% significant level. The money smoothing rate is also significant at 5% significant level. According to Model 2, the inflation coefficient, and the money smoothing coefficients are significant at 5% significant level. The
output gap and the financial stress index coefficients are insignificant at 5% significant level. The inclusion of the financial stress index has reduced both inflation and output gap coefficients. According to Model3, the inflation rate coefficients got further reduced by the inclusion of real effective exchange rate. Moreover the output gap coefficient, the real effective exchange rate coefficient and the financial stress coefficient are all insignificant at 5% significant level in this model. Moreover the R-squared value also got reduced in Model 3 compared to model 1 and 2. These results are compatible with the time varying findings in the past literature (Esanov et al. 2005). The GMM results for China, the M2 growth rate exhibits an insignificant response to the output gap in all three models. The inflation rate coefficients are significant at 5% significant level in all three models. But the exchange rate inclusion has reduced the inflation rate coefficients. This is expected as the real effective exchange rate and the inflation rate are highly negatively correlated. So it can be concluded that the inclusion of the real effective exchange rate in the monetary policy weakens the power of the inflation rate. The financial stress is significant in model 2 while not in model 3. But the exchange rate is significant at 5% significant level in model 3. Most of these GMM results are again compatible with the time varying coefficient estimations in this paper and the past literature (Fan et al. 2010).

The time invariant monetary policy models provide a single coefficient value for a variable. But the time varying model has shown that the coefficients do change significantly during critical economic and financial conditions with respect to their behavior during normal economic conditions. Therefore the time varying model can be considered as a better tool to interpret the monetary policy behavior of a country.
Figure 16: Time Varying Monetary Policy Rule Estimation given the Real Effective exchange rate in the model (M2 Growth rate as the primary policy tool) - BRAZIL

**BRAZIL**

Money Coefficient ($\beta$)

Output Gap Coefficient ($\gamma$)

M2 Growth Rate Smoothing ($\rho$)

Financial Stress Coefficient ($\delta$)

Exchange Rate ($\phi$)

*Note*: The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover, $y$-axis represents the coefficient values.
Figure 17: Time Varying Monetary Policy Rule Estimation given the Real Effective exchange rate in the model (M2 Growth rate as the primary policy tool) - RUSSIA

RUSSIA

Money Coefficient (β)  
Output Gap Coefficient (γ)

Money Smoothing (ρ)  
Financial Stress Coefficient (δ)

Exchange Rate (φ)

Note: The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover y-axis represents the coefficient values.
Figure 18: Time Varying Monetary Policy Rule Estimation given the Real Effective exchange rate in the model (M2 Growth rate as the primary policy tool) - CHINA

CHINA

Inflation Coefficient (β)

Output Gap Coefficient (γ)

Money Smoothing (ρ)

Financial Stress Coefficient (δ)

Exchange Rate (φ)

Note: The Blue line indicates the coefficient values. The Green and Red lines represent the 90% confidence interval bands. Moreover y-axis represents the coefficient values.
This paper analyses the effects of global financial stress in the BRIC country monetary policy setting. A forward looking time varying monetary policy rule is used with other macroeconomic variables such as inflation rate, output gap, real effective exchange rate and financial stress index. The financial stress index of each country is represented by the Emerging country financial stress index which is created by the International Monetary Fund (IMF).

First I analyzed an interest rate rule monetary policy for all countries. Since the results of this model were not compatible with the literature and the general economic intuition, M2 growth rate (Money 2 growth rate) was then considered as the primary monetary policy tool for BRICs. Since BRICs are open economies, the literature has suggested the real effective exchange rate as another variable which determines the monetary policy decisions of these countries. Therefore I also estimated a monetary policy model with real effective exchange rate. I also estimated a time invariant monetary policy to compare the results with the results of the time varying models. Since the explanatory variables; inflation rate, exchange rate, output gap and financial stress are correlated with the error term in the model, an endogeneity correction procedure which has been suggested by Kim and Nelson in 2006 was implemented. The time varying model was estimated using the Varying Coefficient (VC) method. The time invariant estimation was granted by a Generalized Method of Moments (GMM).

The effect of financial stress on the monetary policy setting was insignificant for Brazil and Russia for the entire time period considered. But for China the financial stress effect was significant at 10% significant level during some portions of the 1997 Asian Financial Crisis (1997 March – 1997 August, 1998 February, 1998 June – 1998 September). It is clearly evident that the BRIC countries did not care about the 2008 global financial crisis in their monetary policy settings. However the effect of financial stress on the monetary policy setting during economic turbulence times showed considerable impact. This indicates the monetary easing behavior of the central Banks in BRICs during volatile economic conditions. These considerable effects are intense during local or regional economic crises than during advanced country economic crises.
I also considered the sub components of the original financial stress index (The Banking stress, the security market stress and the exchange rate stress) to understand the composition of the changes in the monetary policy to financial stress. The results suggested that the BRIC country central banks highly responded to exchange rate stress than that for other two sub stresses. This is because of the open market structure of BRICs which transfer the global effects in to the domestic economy.
8. REFERENCES


8. APPENDIX

8.1. Appendix 1

Figure 19: The Banking Stress Component of the IMF Financial Stress Index for the BRICS countries; Brazil, Russia, India, China and South Africa. A higher value indicates a higher stress (Balakrishnan 2009)
Figure 20: The Security Market Stress Component of the IMF Financial Stress Index for the BRICS countries; Brazil, Russia, India, China and South Africa. A higher value indicates a higher stress (Balakrishnan 2009).
Figure 21: The Exchange Market Stress Component of the IMF Financial Stress Index for the BRICS countries; Brazil, Russia, India, China and South Africa. A higher value indicates a higher stress (Balakrishnan 2009).
8.2. Appendix 2:

Figure 22: The Effect of different Leads and Lags of Financial Stress on Monetary Policy Setting (M2 Growth rate as the Policy tool)

Note: These figures show the effect of financial stress on the interest rate rule monetary policy setting. The y-axis is defined as the product of the financial stress indicator and the estimated coefficient ($\delta x$)
I use different leads and lags of the financial stress index to examine the effect of different financial stress paces on the monetary policy setting in BRICs. All the leads and lags of financial stress showed similar fluctuations for Brazil. Higher financial stress effects are reported during 2002 South American Economic Crisis and 2008 global financial crisis. For the Russian Federation, the $FSI_{t-2}$ and $FSI_{t+1}$ show similar fluctuations throughout the time. The current financial stress index behaves in two different ways during 1998 Russian Financial crisis and during 2008 global financial crisis. The time varying behavior of the first lag financial stress effect is more compatible with the economic intuition. However the effects of different financial stress lags and leads do show some mixed time varying behaviors along the time. In China, $FSI_{t-1}$ and $FSI_{t+1}$ have almost similar effects on M2 growth rate during the economic uncertainty times. But $FSI_{t-2}$, $FSI_t$ and $FSI_{t+2}$ show mixed effects on the M2 growth rate. These results suggest that the different financial stress levels act in different ways on the monetary policy settings. Therefore selecting the correct financial stress data stream to the model has to be done according to the economic literature and the economic intuition. Assuming Central Banks consider the most recent financial conditions in to its policy making process, this paper uses the first lag of the financial stress index (Mishkin 2009).
8.3. Appendix 3: The Augmented Dickey Fuller Unit Root Test Results

**BRAZIL**

Table 4: ADF Unit root test results for Brazil

<table>
<thead>
<tr>
<th>Variable</th>
<th>With Drift Term</th>
<th></th>
<th>With Drift + Linear Trend</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ADF test Stat</td>
<td>P Value</td>
<td>ADF Test Stat</td>
</tr>
<tr>
<td>Interest Rate</td>
<td></td>
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<td>-3.1879</td>
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</tr>
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<td>0.3679</td>
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<tr>
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<td>1.79E-05</td>
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<td>-4.5171*</td>
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<td></td>
</tr>
<tr>
<td>Levels</td>
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<td>-3.3647*</td>
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<tr>
<td>First Difference</td>
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<td>-6.0044*</td>
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</table>

**RUSSIA**

Table 5: ADF Unit root test results for RUSSIA

<table>
<thead>
<tr>
<th>Variable</th>
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<th></th>
<th>With Drift + Linear Trend</th>
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<td>P Value</td>
<td>ADF Test Stat</td>
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<td>Interest Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>log Levels</td>
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<td>-3.5082*</td>
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<td></td>
</tr>
<tr>
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<td>0.0013</td>
<td>-4.6644*</td>
<td>0.0008</td>
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<td>First Difference</td>
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<td>8.835E-09</td>
<td>-6.2085*</td>
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<tr>
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<td>-5.0336</td>
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<td>Levels</td>
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<td>First Difference</td>
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<td>1.04E-07</td>
<td>-5.7347*</td>
<td>4.95E-06</td>
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</tbody>
</table>

**Note**: * indicates significant at 5% significant level.
### ADF Unit root test results for China

<table>
<thead>
<tr>
<th>Variable</th>
<th>With Drift Term</th>
<th></th>
<th>With Drift + Linear Trend</th>
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</thead>
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<td>ADF test Stat</td>
<td>P Value</td>
<td>ADF Test Stat</td>
<td>P Value</td>
</tr>
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<td>Interest Rate</td>
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<td>log first Difference</td>
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<td>0.1045</td>
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</tr>
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<td></td>
<td>First Difference</td>
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<td>1.63E-10</td>
<td>-7.1656*</td>
</tr>
<tr>
<td>Inflation_3</td>
<td>Levels</td>
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<td>0.0505</td>
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<td></td>
<td>First Difference</td>
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<td>7.67E-05</td>
<td>-4.7005*</td>
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<td>First Difference</td>
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<td>Levels</td>
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<td>First Difference</td>
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<td>Levels</td>
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<td>0.0658</td>
<td>-3.2830</td>
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</tbody>
</table>

**Note:** * indicates significant at 5% significant level.
8.4. Appendix 4: The VC Method (Schlicht and Ludsteck 2006)

The VC method is a special case of a typical linear regression model. Consider the following linear regression equation.

\[ Y_t = a'x_t + u_t \; ; \; a, x_t \in \mathbb{R}^n, \; u_t \sim N(0, \sigma^2), t = 1, 2, 3, \ldots, T \]  \hspace{1cm} (i)

Now, assume that the coefficients are time varying and follow a random walk. Then the above equation can be replaced by the following two equations. The first equation represents the estimation equation and the second equation is the state equation. There will be \( n \) number of state equations for \( n \) number of time varying parameters.

\[ Y_t = a'_t x_t + u_t \; ; \; u_t \sim N(0, \sigma^2) \]  \hspace{1cm} (ii)

\[ a_{t+1} = a_t + \nu_t \; ; \; \nu_t \sim N(0, \Sigma) \]  \hspace{1cm} (iii)

Therefore the variance-covariance matrix (\( \Sigma \)), which is assumed to be diagonal, is as follows.

\[
\Sigma = \begin{pmatrix}
\sigma_1^2 & 0 & \ldots & 0 \\
0 & \sigma_2^2 & \ldots & 0 \\
\vdots & \vdots & \ddots & \vdots \\
0 & 0 & \ldots & \sigma_n^2
\end{pmatrix}
\]

Define the following matrices.

\[
X = \begin{pmatrix}
x'_1 & 0 & \ldots & 0 \\
0 & x'_2 & \ldots & 0 \\
\vdots & \vdots & \ddots & \vdots \\
0 & 0 & \ldots & x'_n
\end{pmatrix}
T \times Tn
\]

\[
P = \begin{pmatrix}
-l_n & l_n & 0 & \ldots & 0 \\
0 & -l_n & l_n & \ldots & 0 \\
\vdots & \vdots & \ddots & \ddots & \vdots \\
0 & 0 & \ldots & -l_n & l_n
\end{pmatrix}
(T - 1)n \times Tn
\]

\[
y = \begin{pmatrix}
y_1 \\
y_2 \\
\vdots \\
y_T
\end{pmatrix}
T \times 1
\]

\[
u = \begin{pmatrix}
u_1 \\
u_2 \\
\vdots \\
u_T
\end{pmatrix}
Tn \times 1
\]

\[
a = \begin{pmatrix}
a_1 \\
a_2 \\
\vdots \\
a_T
\end{pmatrix}
Tn \times 1
\]

\[
v = \begin{pmatrix}
v_1 \\
v_2 \\
\vdots \\
v_T
\end{pmatrix}
Tn \times 1
\]

Now write the equations (ii) and (iii) in the following format.

\[ y = Xa + u \; ; \; u \sim N(0, \sigma^2 I_T) \]  \hspace{1cm} (iv)

\[ Pa = v \; ; \; v \sim N(0, V), V = I_{T-1} \otimes \Sigma \]  \hspace{1cm} (v)
To estimate the above two equations, it is required to have a model which explains $x$ as a function of $v$ and $u$. This will allow us to calculate the probability distribution of $x$. The above two equations, (i$\nu$) and ($\nu$) do not allow this possibility as the matrix $P$ in equation (v) is of rank $(T - 1)n$ rather $n$. Therefore it cannot be inverted. Therefore $v$ does not have the ability to determine a distinctive $y$ but provides a set of possibilities.

$$A := \{a = P'(PP')^{-1}v + Z\lambda : \lambda \in \mathbb{R}^n\} \quad (vi)$$

According to the above equations, for any $v$ now it is possible to have $a \in A \iff Pa = v$. Therefore the set (vi) and equation (i$\nu$) provide the relationship between $a$ and $v$. Therefore the equation (v) can be modified as follows:

$$a = P'(PP')^{-1}v + Z\lambda \quad (vii)$$

where $\lambda \in \mathbb{R}$ and $Z = \frac{1}{\sqrt{T}} \begin{pmatrix} I_n \\ I_n \\ \vdots \\ I_n \end{pmatrix}$. Moreover $Z$ is a $Tn \times n$ matrix.

Therefore the (i$\nu$) can be modified as,

$$y = u + XP'(PP')^{-1}v + XZ\lambda \quad (viii)$$

Equations (vii) and (viii) are called as the equivalent orthogonally parameterized model because they imply the insights of the equations in the original model (i$\nu$) and ($\nu$). The orthogonally parameterized model implies a random walk in $a$. Further the model implies that the values for $a$ depend on the past and future realizations of $v_t$. Orthogonal parameterization has its own advantages over the typical parameterization by initial values (Schlicht and Ludstech 2006). The results from an initial value parameterization fully depend on the accuracy of the initial values. Also it requires the model to run back and forth until it finds the tentative initial values (Akaike 1989). However the orthogonal parameterization provides an explicit likelihood function to estimate all relevant parameters directly (Schlicht 1985).

The equation (viii) can be modified as follows.

$$y = XZ\lambda + w \quad (ix)$$
Where
\[ w = u + X P' (PP')^{-1} v, w \sim N (0, W) \]  
where \( W = XBX' + \sigma^2 I_T \)

(x)

With;
\[ B = P' (PP')^{-1} V (PP')^{-1} P \]

(xi)

Then express the matrix of observations in the following conventional format.
\[ X^* = \sqrt{T} XZ = X \begin{pmatrix} l_n \\ \vdots \\ l_n \end{pmatrix} = \begin{pmatrix} x'_1 \\ x'_2 \\ \vdots \\ x'_{T} \end{pmatrix} \]

(x)

By inserting (x) in to (ix), the following linear regression model can be derived.
\[ y = \frac{1}{\sqrt{T}} X^* \lambda + w \]

(xi)

The above equation represents a standard GLS regression, \( y = \beta X^* + w \), with coefficients, \( \hat{\beta} = \frac{1}{\sqrt{T}} \hat{\lambda} \). Further \( \hat{\lambda} \) satisfies the following relationship.
\[ \hat{\lambda} = (Z'X'W^{-1}XZ)^{-1} Z'X'W^{-1} y \]

(xii)

Now take the expectation of equation (vii) and substitute \( \hat{\lambda} \) with \( \lambda \). Then the following equation can be derived.
\[ Z' a = \lambda \]

(xiii)

GLS regression coefficient becomes  \( \beta_i = \frac{1}{T} \sum_{t=1}^{T} a_{i,t} \) where \( i = 1, 2, 3, ..., n \).

Schlicht finds the following relationship as the best way to find the vector of parameters in \( a \). This relationship minimizes the weighted sum of squares of all the error terms associated in the model.
\[ \sum_{i=1}^{T} u^2 + \theta_1 \sum_{i=1}^{T} v_1^2 + \theta_2 \sum_{i=1}^{T} v_2^2 + \theta_3 \sum_{i=1}^{T} v_3^2 + \ldots + \theta_n \sum_{i=1}^{T} v_n^2 \]

(xiv)

Where the inverse variance ratios between \( u \) and \( v \) is \( \theta_i = \sigma^2 / \sigma_i^2 \). Therefore the estimator provides the parameter stability and best fit of the model. The estimated disturbances are as follows (Schlicht 2006).
\[ \hat{u} = y - X\hat{a} \]

(xv)
\[ \hat{v} = P\hat{a} \]

(xvi)
The estimated disturbances together with the weighted sum of squares minimization equation above provide the following relationship (Schlicht 2006).

$$(X'X + \sigma^2 P'V^{-1} P)\tilde{\alpha} = X'y$$

This equation will be used to estimate the relevant coefficients for the model. The estimation process has two steps. First the coefficients are estimated using equations (xv) and (xvi). Second, the estimated residuals are calculated through (xiv) and their estimated second moments $\hat{\sigma}^2$ and $\hat{\sigma}^2$ are compared to their expected moments $E[\hat{\sigma}^2]$ and $E[\hat{\sigma}^2]$. These steps are repeated until the estimated moments are identical to their corresponding expected values.
8.5. Appendix 5: The Time Flow of - Bank Rate, M2 Growth Rate, Industrial Production Index, Exports and GDP Growth Rate

**BRAZIL**

**Discount_Rate**

**M2_ Growth Rate**