# The Impact of Monetary Policy on Economic Growth and Inflation in Sri Lanka

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## *Abstract*

*Based on a vector autoregressive (VAR) framework and utilising both recursive and structural specifications, this study analyses the effects of interest rate, money growth and the movements in nominal exchange rate on real GDP growth and inflation in Sri Lanka for the period from 1978 to 2005.*

*The results of the recursive VARs are broadly in line with the established empirical findings, especially when the interest rate is considered the monetary policy variable. Following a positive innovation in interest rate, GDP growth and inflation decrease while the exchange rate appreciates. When money growth and exchange rate are used as policy indicators, the impact on GDP growth contrasts with established findings. However, as expected, an exchange rate appreciation has an immediate impact on the reduction of inflation. Interest rate innovations are persistent, supporting the view that the monetary authority adjusts interest rates gradually, while innovations in money growth and exchange rate appreciation are not persistent. Several puzzling results emerge from the study: for most sub-samples, inflation does not decline following a contractionary policy shock; innovations to money growth raises the interest rate; when inflation does respond, it reacts to monetary innovations faster than GDP growth does; and exchange rate appreciations almost always lead to an increase in GDP growth.*

*The results from the semi-structural VARs, which impose identification restrictions only on the policy block, are not different from those obtained from recursive VARs. The results show that none of the sub-samples since 1978 can be identified with a particular targeting regime. In contrast, the interest rate, monetary aggregates and the exchange rate, contain important information in relation to the monetary policy stance. Based on this premise, a monetary policy index is estimated for Sri Lanka. The index displays that unanticipated monetary policy forms a smaller portion of monetary policy action in comparison to anticipated monetary policy. It is also observed that a decline in GDP growth is associated with anticipated policy with a short lag, while reductions in inflation are associated with both anticipated and unanticipated components of monetary policy with a longer lag of 28 to 36 months.*


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# 1. Introduction

The objective of this paper is to assess the effects of monetary policy on economic growth and inflation in the small open developing economy of Sri Lanka. To this end, this paper presents the results of an empirical investigation using monthly data for the period from 1978 to 2005. The specific contribution of this paper is to measure the impact of monetary policy – as measured by the movements of interest rates, money growth and the exchange rate – utilising the semi-structural VAR methodology *a la* Bernanke and Mihov (1995), where identifying restrictions are imposed only on the policy block of variables. Using the Bernanke and Mihov methodology also facilitates the derivation of a monetary policy index for Sri Lanka, and the implications of the index are also discussed briefly.

The paper is organised as follows: Section 1 provides an introduction to the established evidence on the effects of monetary policy in the long-run and short run as well as a brief introduction to monetary policy in Sri Lanka. Section 2 reviews the existing literature with regard to the methods of assessing the effects of monetary policy on macroeconomic variables. Section 3 explains the methodology and data used in the analysis. Section 4 analyses the results obtained while Section 5 summarises and concludes the discussion.

## 1.1 Relationship between Money, Output and Prices

There is a general agreement among economists in relation to the long run relationship between money, output and inflation. However, this consensus becomes blurred with regard to short run relationships. Understanding both long run and short run relationships is essential for the conduct of monetary policy since a central bank aims to influence the macroeconomic variables mainly through regulating the cost and availability of money (i.e., interest rates and credit availability). Although monetary aggregates have increasingly fallen out of favour as intermediate targets, the relationship between monetary policy and macroeconomic variables is unquestionably at the heart of the study of monetary economics.

McCandless and Weber (1995) examine data for 110 countries over a 30-year period, and obtain correlations revealing three long-run monetary facts: (a) there is a high (almost unity) correlation between the rate of growth of the money supply and the rate of inflation, (b) there is no correlation between the growth rates of money and real output with the exception of a subsample of countries in the OECD, where the correlation seems to be positive, and (c) there is no correlation between inflation and real output growth. Walsh (2003) explains that McCandless and Weber's analysis "provide evidence on relationships that are unlikely to be dependent on unique, country-specific events (such as the particular means employed to implement monetary policy) that might influence the actual evolution of money, prices, and output in a particular country" (p.9). According to Walsh, the high correlation between inflation and the growth rate of money supply supports the quantity-theoretic argument that the growth of money supply leads to an equal rise in the price level. Romer (2006) also confirms this view: “when it comes to understanding inflation over the longer term, economists typically emphasize just one factor: growth of the money supply” (p.497). Geweke (1986) finds that money is superneutral on its effects on real output growth while Boschen and Mills (1995) display that in the United States, permanent monetary shocks do not contribute to permanent shifts in real output. McCandless and Weber (1995) argue that “[w]hile correlations are not direct evidence of causality, they do lend support to causal hypotheses that yield predictions consistent with the correlation” (p.2). Further, they maintain that if these correlations can be interpreted as causal relationships, they suggest that long-run inflation can be adjusted by adjusting the growth rate of money, while “the fact that the growth rates of money and real output are not correlated suggests that monetary policy has no long-run effects on real output” (p.4).

Although the long-run monetary facts explained above reveal that money or monetary policy could only affect the nominal variables in the long run, with little or no effect on real variables, they do not rule out the fact that monetary policy could also have real effects in the short-run. With regard to the relationship between money and prices, King (2002) shows that the strong correlation between them disappears as the time horizon shortens indicating that the effects of money growth should emerge in the changes in real variables. Moreover, Walsh (2003) demonstrates that, “[t]he consensus from the empirical literature on the short-run effects of money is that exogenous monetary policy shocks produce hump-shaped movements in real economic activity. The peak effects occur after a lag of several quarters (as much as two or three years in some of the estimates) and then die out” (p.40). Blanchard and Fischer (1989) also show that “[n]ominal interest rate innovations are positively correlated with current and lagged GNP innovations but negatively correlated with GNP two to five quarters later” (p.19).

Unlike long-run relationships, the short-run correlations do not provide conclusive evidence on causal relationships. For instance, Tobin (1970) shows that Friedman and Schwartz’s (1963) argument that money leads output movements could be reinterpreted as output innovations lead to changes in money growth, as monetary authorities react to the state of the economy. Walsh (2003) explains that since the short-run relationships between money, inflation, and output incorporate reactions of private economic agents as well as the monetary authority to economic disturbances, “short-run correlations are likely to vary both across countries, as different central banks implement policy in different ways, and across time in a single country, as the sources of economic disturbances vary” (p.12).

## 1.2 Monetary Policy in Sri Lanka

Similar to many central banks especially in developing economies, the objectives of the Central Bank of Sri Lanka (CBSL) were stabilisation of the domestic value of the rupee, stabilisation of the external value of the rupee, and promotion of economic growth. However, the CBSL has increasingly focussed on the stabilisation objectives than the development objective, and with the amendments in 2002 to the Monetary Law Act under which the CBSL is established, these objectives were revised in accordance with the international trends in central banking and are now stated as maintaining economic and price stability and maintaining financial system stability.

The CBSL has gradually moved away from direct controls towards more market oriented policy tools since 1977. While credit controls were gradually eliminated and the administratively determined bank rate was gradually abandoned, the CBSL has increasingly utilised open market operations for the conduct of monetary policy. The floating of the exchange rate in 2001 has added to the operational independence of monetary policy.

Currently, the CBSL conducts monetary policy based on a monetary targeting framework with interest rates as the policy instrument, with the view of achieving economic and price stability. A monetary programme is prepared "considering the economic outlook of the country and projections based on the desired rate of monetary expansion to achieve a target rate of inflation, consistent with the projected rate of economic growth, balance of payments forecast and expected fiscal operations of the government. Accordingly, a reserve money target is established, which is the operating target for monetary policy" (Jayamaha *et al* (2001/02), p.17).

To meet the reserve money targets, open market operations are conducted with Repo and reverse Repo rates as the key policy instruments forming the lower and upper bounds of the interest rate corridor in which the interbank call money market operates. However, in practice, the fact that the CBSL is also concerned about movements of exchange rates, economic growth, as well as bi-directional relationships between monetary and fiscal policies cannot be ruled out.

## 2. Literature Review

### 2.1 Different Approaches of Measuring the Effects of Monetary Policy

Perhaps the most important problem in measuring the effects of monetary policy is its endogeneity. This arises because the monetary authorities respond to macroeconomic conditions similar to other economic agents, and therefore, "[t]he question of practical importance in central banking is never "should we create some random noise this month?," but rather "does this month's news justify a change in the level of interest rates?"" (Woodford (2003), p.7). One of the earliest attempts to tackle this problem of endogeneity in analysing the effects of monetary policy on macroeconomic variables is the work of Friedman and Schwartz (1963) who use a historical method to isolate exogenous monetary policy shocks. More recent examples for the use of historical analysis of monetary policy are Romer and Romer (1989) and Boschen and Mills (1991). Bernanke and Mihov (1995) appreciate the Romer and Romer, and Boschen and Mills approaches for "being "nonparametric", in that its implementation does not require any modelling of the details of the Fed's operating procedures or of the financial system and is potentially robust to changes in those structures" (p.4). However, the historical or "narrative" approach of Friedman and Schwartz, Romer and Romer, and Boschen and Mills, "are of little use in determining the details of policy's effects. For example, because Friedman and Schwartz and Romer and Romer identify only a few episodes, their evidence cannot be used to obtain precise quantitative estimates of policy's impact on output or to shed much light on the exact timing of different variables' responses to monetary changes" (Romer (2006), p.262). Also, several economists including Bernanke and Mihov (1995), and Leeper, Sims, and Zha (1996) show that the narrative indices are inherently subjective and "capture both exogenous shifts in policy and the endogenous response of monetary policy to economic developments" and "that most movements in monetary policy instruments represent responses to the state of the economy, not exogenous policy shifts" (Walsh (2003), p.39).

The major class of alternatives to the historical approach is time series macroeconometrics, and early examples of this approach include Friedman and Meiselman (1963), Andersen and Jordon (1968), Sims (1972), and Barro (1977, 1978, 1979). During the 1960s and early 1970s economists used large-scale structural macroeconometric models to assess the effects of monetary policy. According to Walsh (2003), "[a] key maintained hypothesis, one necessary to justify this type of analysis, was that the estimated parameters of the model would be invariant to the specification of the policy rule" (p.35). However, this hypothesis was challenged by Lucas (1976), who argues that expectations adjust adaptively to past outcomes and therefore the parameters of the model would not be invariant. This changed the course of macroeconomics drastically and Sims (1980) provides an easy alternative for economists to analyse the effects of monetary policy on macroeconomic variables through the introduction of vector autoregression (VAR) to monetary economics.

## 2.2 The Use of VARs in Measuring the Effects of Monetary Policy

Walsh (2003) explains the evolution of VARs as follows: "[t]he use of VARs to estimate the impact of money on the economy was pioneered by sims (1972, 1980). The development of the approach as it has moved from bivariate (Sims 1972) to trivariate (Sims 1980) to larger and larger systems" (p.24). Lütkepohl (2004) argues that VARs "are a suitable model class for describing the data generation process (DGP) of a small or moderate set of time series variables. In these models all variables are often treated as being *a priori* endogenous, and allowance is made for rich dynamics. Restrictions are usually imposed with statistical techniques instead of prior beliefs based on uncertain theoretical considerations" (p.86). Stock and Watson (2001) show that there are three varieties of VARs, namely, reduced form, recursive and structural. Reduced form VARs impose no structure on the system, and Cooley and LeRoy (1985) argue that "[e]arly VARs put little or no structure on the system. As a result, attempts to make inferences from them about the effects of monetary policy suffered from the same problems of omitted variables, reverse causation, and money-demand shifts that doom the St.Louis equation" (p.283).

Through the introduction of structural VARs, Economists then attempted to bring in theoretical foundations to the system through various identification schemes. Breitung, Brüggemann, and Lütkepohl (2004) show that "[i]nstead of identifying the (autoregressive) coefficients, identification focuses on the errors of the system, which are interpreted as (linear combinations of) exogenous shocks" (p.159). Attempts are made to incorporate identification structures to the system through ordering of variables that resulted in recursive VARs, a first step towards structural identification. Stock and Watson (2001) distinguish between recursive and structural VARs as follows: "recursive VARs use an arbitrary mechanical method to model contemporaneous correlation in the variables, while structural VARs use economic theory to associate these correlations with causal relationships. Unfortunately, in the empirical literature the distinction is often murky. It is tempting to develop economic "theories" that, conveniently, lead to a particular recursive ordering of the variables, so that their "structural" VAR simplifies to a recursive VAR, a structure called a 'Wold causal chain'" (p.112). Major works on structural VARs include Bernanke (1986), Blanchard and Watson (1986), Sims (1986), Shapiro & Watson (1988), and Blanchard and Quah (1989).

Within Structural VARs, Blanchard and Quah (1989) as well as King, Plosser, Stock and Watson (1991) promote the use of long-run restrictions such as the long-run neutrality of money to identify monetary policy shocks. Important work involving short-run restrictions include Sims (1986), Gorden and Leeper (1994), Leeper, Sims, and Zha (1996), Sims and Zha (1998), and Christiano, Eichenbaum, and Evans (1996, 1999) They impose contemporaneous restrictions on all economic variables in a VAR system. An interesting alternative is the method suggested by Bernanke and Mihov (1995), which divides the variables into policy and non-policy sectors, and imposes short run restrictions only on the policy sector. Whatever the identification scheme is used, according to Villani and Warne (2003), "successful application of structural VARs hinges on a proper identification of the structural shocks" (p.14).

Results of VARs are typically analysed using Granger-causality tests, impulse responses and forecast error variance decompositions. Using these techniques, practitioners who use VARs have obtained results that make economic sense. Sims (1992) who estimates monetary VARs for France, Germany, Japan, the United Kingdom, and the United States, finds that monetary shocks lead to a hump-shaped output response, where the negative effect of a contractionary shock on output peaks after several months and then gradually disappears. Christiano, Eichenbaum and Evans (1996) present stylised facts on the VAR responses to a contractionary monetary shock: the initial response of the price level is small; interest rate rises initially; and the initial output response is negative with no long run impact. Christiano, Eichenbaum and Evans (1999) confirm their earlier findings as follows: "after a contractionary monetary policy shock, short term interest rates rise, aggregate output, employment, profits and various monetary aggregates fall, the aggregate price level responds very slowly, and various measures of wages fall, albeit by very modest amounts" (p. 69).

There is little consensus, however, on the use of variance decompositions to interpret VAR results. In the VAR analysis, Policy shocks are usually found to explain only a limited amount of variance in output or inflation. For instance, Christiano, Eichenbaum, and Evans (1999) find that a very small variance of the price level can be attributed to monetary policy shocks. This is attributed to the anticipated monetary policy playing a major role in contrast to unanticipated monetary policy. Leeper, Sims, and Zha (1996) explain that "[a]nother robust conclusion […] is that a large fraction of the variation in monetary policy instruments can be attributed to the systematic reaction of policy authorities to the state of the economy. This is what one would expect of good monetary policy" (p.2). Bernanke and Mihov (1995) also discourage the use of variance decompositions.

A researcher faces a great dilemma when it comes to selecting variables to be included in the VAR. Christiano, Eichenbaum, and Evans (1996) show that "we would like, in principle, to include all of the variables in our analysis in one large unconstrained VAR and report the implied system of dynamic response functions. However, this strategy is not feasible because of the large number of variables which we wish to analyze. […] On the other hand, if we include too few variables in the VAR then we would encounter significant omitted variable bias" (p.18). Therefore, researchers have traditionally included an indicator of aggregate economic activity, an indicator of inflation, and a monetary policy variable at a minimum. Other variables which are "of potential interest to the [monetary authority] can be included either because they represent ultimate policy objectives or because they provide information about these objectives" (Kasa and Popper (1997), p.285).

The other problem in relation to the choice of variables is when there is no clear single policy variable. "There is a long tradition in monetary economics of searching for a single policy variable – perhaps a monetary aggregate, perhaps an interest rate – that is more or less controlled by policy and stably related to economic activity. Whether the variable is conceived of as an indicator of policy or a measure of policy stance, correlations between the variable and macroeconomic time series are taken to reflect the effects of monetary policy" (Leeper, Sims, and Zha (1996), p.1).

Studies using different policy variables have led to conflicting results and Walsh (2003) argues that "The exact manner in which policy is measured makes a difference, and using an incorrect measure of monetary policy can significantly affect the empirical estimates one obtains" (p.40). Early VARs such as Sims (1980) and Litterman and Weiss (1985) use money stock as the policy variables but find that the inclusion of interest rates tend to absorb the predictive power of money. McCallum (1983) argues that this finding does not mean that monetary policy is ineffective, but instead the interest rate is perhaps a better indicator of monetary policy. Building on this argument, Bernanke and Blinder (1992) use a short-term interest rate or an interest rate spread. Christiano and Eichenbaum (1992), and Christiano, Eichenbaum, and Evans (1996) use non-borrowed reserves while Strongin (1995) uses the portion of non-borrowed reserves that is orthogonal to total reserve growth as the monetary policy variable.

In relation to the choice of policy variables, Bernanke and Mihov's (1995, 1998) analysis make some important contributions. Arguing that "it may be the case that we have only a vector of policy indicators […] which contain information about the stance of policy but are affected by other forces as well" (Bernanke and Mihov (1995), p.10), they study the reserve market carefully to identify monetary policy shocks rather than simply assuming a monetary policy indicator, thereby allow for more than one policy variable in the VAR. Bernanke and Mihov (1998) list the advantages of their method as follows: "[f]irst, because our specification nests the best known quantitative indicators of monetary policy used recently in VAR modelling, including all those mentioned above, we are able to perform explicit statistical comparisons of these and other potential measures, including hybrid measures that combine the basic indicators. Second, our analysis leads directly to estimates of a new policy indicator that is optima, in the sense of being most consistent with the estimated parameters describing the central bank's operating procedure and the market for bank reserves. Third, by estimating the model over different sample periods, we are able to allow for changes in the structure of the economy and in operating procedures, while imposing a minimal set of identifying assumptions. Finally, although we consider only the post-1965 US case in this paper, our method is applicable to other countries and periods, and to alternative institutional setups" (p.872). Accordingly, several researchers have adopted the Bernanke-Mihov approach *mutatis mutandis* for different economies and policy frameworks. Fung (2002), who uses this methodology to analyse the effects of monetary policy in several East Asian countries, shows that it has been applied to Germany (Bernanke and Mihov (1997)), Italy (De Arcangelis and Di Giorgio (1998)) and Canada (Fung and Yuan (2000)). Some other applications are Kasa and Popper (1997) and Nakashima (2004) who apply the methodology to Japan, Piffanelli (2001) to Germany, and De Arcangelis and Di Giorgio (2001) to Italy.

VARs do not always result in interpretable results. Eichenbaum (1992), and Gordon and Leeper (1994) discuss how different measures of policy shocks can produce "puzzles" or results contrary to existing theoretical explanations. Typical puzzles have included the liquidity puzzle where interest rates decline following innovations in money, price puzzle where prices fall immediately following a contractionary shock, and exchange rate puzzle where contractionary monetary policy leads to a depreciation of the domestic currency.

Several economists have attempted to address the puzzling results obtained from VARs. For instance, in relation to the prize puzzle, economists have argued that the variables included in the VARs do not control for the information set of the monetary authorities, and including forward-looking variables in the VAR system often solves the puzzle. Sims (1992), Chari, Christiano, and Eichenbaum (1995), Christiano, Eichenbaum, and Evans (1996, 1999) show that commodity prices or nominal exchange rate can be included in the VARs as proxies for forward-looking information of monetary authorities.

In addition to the simple solution of incorporating one or two forward-variables to the VAR to address the prize puzzle, there have been at least two advanced methods of broadening the data horizon covered in VAR systems, the first is by using Baysian VARs while the second is the use of Factor-augmented VARs.

Stock and Watson (1996) argue that "small VARs of two or three variables are often unstable and thus poor predictors of the future [but] adding variables to the VAR creates complications" (p.110). In order to address this problem, Stock and Watson (2001) show that Litterman (1986) pioneered the use of Baysian methods which impose a common structure on the coefficients. McNees (1990), Sims (1993), and Villani and Warne (2003) are some important work that use Baysian VARs.

Bernanke, Boivin, Eliasz (2004, 2005) use a novel method to address potential problem of the information set being too small and real activity often not being adequately represented. Using factor analysis, they summarise information from a large number of macroeconomic time series by a relatively small set of estimated indexes, or factors, which are then used to augment standard VARs. Lagana and Mountford (2005) carry out a similar FAVAR framework for the UK monetary policy.

Many attempts have been made to extend benchmark closed economy VAR models to open economies. Such extensions usually add foreign variables such as foreign interest rates and inflation, as well as the exchange rate movements to the VAR specification. Using a two-economy model Eichenbaum and Evans (1995) "find that a contractionary shock to US monetary policy leads to (i) persistent, significant appreciation in US nominal and real exchange rates and (ii) persistent decreases in the spread between foreign and US interest rates, and (iii) significant, persistent deviations from uncovered interest rate parity in favor of US investments" (Christiano, Eichenbaum, and Evans (1999), pp.94-95).

However, according to Christiano, Eichenbaum, and Evans (1999) "[i]dentifying exogenous monetary policy shocks in an open economy can lead to substantial complications relative to the closed economy case" (p.94). As De Arcangelis and Di Giorgio (2001) explain, these difficulties "are usually due to the simultaneous reaction between interest and exchange rate innovations, which in turn, can be responsible for the emergence of new empirical puzzles, as the one of an impact depreciation of the exchange rate following a monetary policy contraction in the domestic country" (p.82). Vonnák, (2005) further explains that that "[d]ue to the quick reaction of monetary policy to exchange rate movements and the exchange rate to monetary policy surprises, the simultaneity problem seems to be highly relevant, ruling out *a priori* the adoption of recursive identification" (p.9). Favero (2001) concludes that "[v]arious papers have examined the effects of monetary shocks in open economies, but this strand of literature has been distinctly less successful in providing accepted empirical evidence than the VAR approach in closed economies" (p.180).

The interaction between exchange rates and interest rates, which is at the heart of the open economy framework has attracted much attention in recent times. Structural identification schemes to address this issue have been introduced by Kim and Roubini (2000), and by Cushman and Zha (1997), who incorporate the trade sector into the VAR specification. Ball (1998, 2000) among others, attempts to include exchange rates into traditional policy rules, while many central banks have devised "monetary conditions indices" based on both interest rates and exchange rates.

A discussion on measuring the effects of monetary policy using VARs will be incomplete if various criticisms on VARs are not examined. VARs have been criticised on several grounds by Sheffrin (1995), Rudebusch (1998) and McCallum (1999), etc. With regard to identification restrictions, this method has been subjected to various criticisms including the arbitrary ordering and identification assumptions. Many argue that some impulse responses contradicts economists' priors, residuals from VAR regressions are not compatible with the findings of others who use historical analyses with regard to contractionary and expansionary policies, and the policy reaction functions implied in VARs are different to those obtained using other direct methods.

Other criticism includes that VAR accounts for only unanticipated shocks, that VAR does not identify the effects of systematic monetary policy rules, and that VARs usually use final data that are not available to policymakers at the time of making monetary policy decisions.

Counter-arguments to these criticisms have been presented by Sims (1998) and Stock and Watson (2001) etc., and many of the criticisms have been met by various improvements to VARs as described above, while many improvements that are needed are identified. For instance, Sims (1998) states that "[t]he restriction of identified VAR modeling to handling only either just-identified models or over-identified models that restrict only contemporaneous coefficients is artificial. It is time for some move in the direction of relaxing this computationally based constraint" (p.941). Although economists are yet to reach a consensus, VARs provide a useful and practical tool for applied monetary economists to measure the effects of monetary policy.

However, an irony remains valid with regard to the present-day VAR methodology. Breitung, Brüggemann, and Lütkepohl (2004) summarise this as follows: "it may be worth remembering that Sims (1980) advocated VAR models as alternatives to econometric simultaneous equations models because he regarded the identifying restrictions used for them as "incredible." Thus, structural VAR modelling may be criticized on the same grounds" (p.195-196).

## 3. Hypotheses and Methodology

The key hypotheses that will be tested in this paper is whether empirical evidence from Sri Lanka on the effects of monetary policy on output and prices obtained from VARs accords with the existing theoretical explanations and empirical findings. Specifically, it will be tested whether output growth and inflation declines following a contractionary monetary policy shock, whether the reaction of output growth to monetary policy is faster than the reaction of inflation to monetary policy, whether money supply contracts following an increase in the interest rate, and finally, whether the exchange rate appreciates following an increase in the interest rate.

To test the above hypotheses, VARs with recursive structures as well as semi-structural VARs with a structure imposed only on the policy block, in the lines of Bernanke and Mihov (1995, 1998) will be utilised. Although a general discussion on estimation of a reduced form VAR methodology is avoided since it is widely available in textbooks on time-series econometrics such as Lütkepohl (1993), Hamilton (1994) and Enders (2004), the recursive identification methodology and the Bernanke-Mihov methodology are described below. Prior to that, a brief discussion on the requirement of statistical identification is provided.

Breitung, Brüggemann, and Lütkepohl (2004) discuss the problem of statistical identification and show that "structural shocks are the central quantities in an SVAR model" and "[t]he shocks are associated with an economic meaning such as an oil price shock, exchange rate shock, or a monetary shock. Because the shocks are not directly observed, assumptions are needed to identify them" (p.161). Supposing the relationship between the elements of VAR residuals and structural residuals (shocks) take the form

$$Au = Bv \tag{3.01}$$

which relates the reduced-form disturbances $u$ to the underlying structural shocks $v$. Breitung, Brüggemann, and Lütkepohl (2004) show that the most popular kinds of restrictions used in structural VAR models "can be classified as follows: [2]

i) $B=I_K$. The vector of innovations $v_t$ is modeled as an interdependent system of linear equations such that $Au=v$…

ii) $A=I_K$. In this case the model for the innovations is $u=Bv$…

iii) The so-called *AB*-model of Amisano & Giannini (1997) combines the restrictions for *A* and *B* from (i) and (ii)…

iv) There may be prior information on the long-run effects of some shocks. They are measured by considering the responses of the system variables to the shocks…" (p.163).

Given this framework, they compute the number of restrictions required to identify a Structural VAR: "The number of parameters of the reduced form VAR (leaving out the parameters attached to the lagged variables) is given by the number of nonredundant elements of the covariance matrix $\Sigma_u$, that is, K(K+1)/2. Accordingly, it is not possible to identify more than K(K+1)/2 parameters of the structural form. However, the overall number of elements of the structural form matrices A and B is $2K^2$. It follows that

$$2K^2 - \frac{K(K+1)}{2} = K^2 + \frac{K(K-1)}{2} \tag{3.02}$$

restrictions are required to identify the full model. If we set one of the matrices *A* or *B* equal to the identity matrix, then K(K-1)/2 restrictions remain to be imposed" (p.163). For instance, a "recursive structure implies just the required K(K-1)/2 zero restrictions" (P.164).

### *Recursive VAR Methodology*

Recursive VARs as explained by Sims (1980) based on the Choleski decomposition of matrices, are the simplest among the structural VAR schemes. In terms of equation (3.01), the *A* and *B* matrices then take the form;

$$A = \begin{bmatrix} 1 & 0 & 0 & . & 0 \\ a_{21} & 1 & 0 & . & 0 \\ . & . & 1 & . & . \\ a_{n1}. & . & . & a_{nn-1} & 1 \end{bmatrix}, \quad B = \begin{bmatrix} b_{11} & 0 & 0 & . & 0 \\ 0 & b_{22} & 0 & . & 0 \\ . & . & b_{ii} & . & . \\ 0 & 0 & 0 & . & b_{nn} \end{bmatrix}. \tag{3.03}$$

[2] Throughout Sections 3 and 4, notation has been changed to maintain consistency.

Favero (2001) further notes that "[t]his is obviously a just-identification scheme, where the identification of structural shocks depends on the ordering of variables. It corresponds to a recursive economic structure, with the most endogenous variables ordered last" (p. 165).

Expanding, this decomposition results in,

$$\begin{bmatrix} 1 & 0 & 0 & . & 0 \\ a_{21} & 1 & 0 & . & 0 \\ . & . & 1 & . & . \\ a_{n1} . & . & . & a_{nn-1} & 1 \end{bmatrix} \begin{bmatrix} u^1 \\ u^2 \\ u^i \\ . \\ u^n \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & . & 0 \\ 0 & b_{22} & 0 & . & 0 \\ . & . & b_{ii} & . & . \\ 0 & 0 & 0 & . & b_{nn} \end{bmatrix} \begin{bmatrix} v^1 \\ v^2 \\ v^i \\ . \\ v^n \end{bmatrix} \quad (3.04)$$

that is,

$$\begin{bmatrix} 1 & 0 & 0 & . & 0 \\ a_{21} & 1 & 0 & . & 0 \\ . & . & 1 & . & . \\ a_{n1} . & . & . & a_{nn-1} & 1 \end{bmatrix} \begin{bmatrix} u^1 \\ u^2 \\ u^i \\ . \\ u^n \end{bmatrix} = \begin{bmatrix} b_{11} v^1 \\ b_{22} v^2 \\ b_{ii} v^i \\ . \\ b_{nn} v^n \end{bmatrix} \quad (3.05)$$

Although Sims (1980) used the monetary policy variables first on the assumption that policy does not respond to the contemporaneous movements in macroeconomic variables (mainly due to macroeconomic variables being unobserved contemporaneously), later analysts such as Bernanke and Blinder (1992) have ordered the policy instrument last.

The recursive VAR structure and the notation used by Bernanke and Blinder (1992) are worth noting as a preamble to introducing the Bernanke-Mihov methodology. Bernanke and Blinder assume that the "true" economic structure can be written as,

$$Y_t = \sum_{i=0}^{k} B_i Y_{t-i} + \sum_{i=0}^{k} C_i p_{t-i} + A^y v_t^y \quad (3.06)$$

$$p_t = \sum_{i=0}^{k} D_i Y_{t-i} + \sum_{i=1}^{k} g_i p_{t-i} + v_t^p \quad (3.07)$$

where *Y* represents non-policy variables and *p* is the policy variable, and *A, B,C,D, and g* are relevant matrices and vectors as defined in traditional VAR methodology. To identify this system econometrically restrictions are needed. Equating *D* to 0 means that the policy variable is ordered first since non-policy variables will then, not have a contemporaneous effect on policy. In a system where *i*=0,1, this means that

$$p_t = D_1 Y_{t-1} + g p_{t-1} + v_t \qquad (3.08)$$

and

$$Y_t = (I - B_0)^{-1}\left[(B_1 + C_0 D_1) Y_{t-1} + (C_0 g + C_1) p_{t-1} + u_t + C_0 v_t\right] \qquad (3.09)$$

Alternatively, if C=0, the policy variable would be ordered last, and

$$Y_t = (I - B_0)^{-1}\left[B_1 Y_{t-1} + C_1 p_{t-1} + u_t\right] \qquad (3.10)$$

and

$$p_t = \left(D_1 + D_0 (I - B_0)^{-1} B_1\right) Y_{t-1} + \left(g + D_0 (I - B_0)^{-1} C_1\right) p_{t-1} + v_t + D_0 (I - B_0)^{-1} u_t \quad (3.11)$$

### *Bernanke-Mihov Methodology*

Bernanke and Blinder's policy variable *p* is a scalar measure (i.e., interest rate or interest rate spread). However, as explained in section 2, and as Bernanke and Mihov (1998) show "[i]t may be the case that we have only a vector of policy indicators *P*, which contains information about the stance of policy" (p.875). If so,

$$Y_t = \sum_{i=0}^{k} B_i Y_{t-i} + \sum_{i=1}^{k} C_i P_{t-i} + A^y v_t^y \qquad (3.12)$$

$$P_t = \sum_{i=0}^{k} D_i Y_{t-i} + \sum_{i=0}^{k} G_i P_{t-i} + A^p v_t^p \qquad (3.13)$$

With *u* indicating an (observable) VAR residual and *v* indicating an (unobservable) structural disturbance, any policy shock can be measured as,

$$u_t^p = (I - G_0)^{-1} A^p v_t^p \qquad (3.14)$$

or ignoring the subscripts and superscripts,

$$u = Gu + Av \qquad (3.15)$$

Bernanke and Mihov (1995) then introduce their "“semi-structural” VAR model which leaves the relationships among macroeconomic variables in the system unrestricted, but imposes contemporaneous identification restrictions on a set of variables relevant to the market for commercial bank reserves" (p.2). Specifically, they use the Federal funds rate, non-borrowed reserves, borrowed reserves and total reserves in their model of the reserves market. They assume that one element of the vector $v^p$ is a policy disturbance, while it could also include "shocks to money demand or whatever disturbances affect the policy indicators" (pp.10-11), and use different restrictions based on various assumptions on the market for commercial bank reserves to identify policy shocks and their effects on macroeconomic variables.

The relationships between non-policy variables and policy variables in the Bernanke-Mihov methodology are summarised by De Arcangelis and Di Giorgio (2001). According to them "[i]n the estimation of the orthogonalized, economically meaningful (structural) innovations in the second stage, a recursive causal block-order is assumed to form the set of non policy variables to the set of policy variables. Moreover, the recursive causal order is also established for the nonpolicy variables in y. In terms of the relationship between the fundamental innovations, $u_y$ and $u_p$ and the structural innovations $v_y$ and $v_p$ which are mutually and serially uncorrelated, this implies

$$\begin{pmatrix} A_{1,1} & 0 \\ A_{2,1} & A_{2,2} \end{pmatrix} \begin{pmatrix} u_y \\ u_p \end{pmatrix} = \begin{pmatrix} B_{1,1} & 0 \\ 0 & B_{2,2} \end{pmatrix} \begin{pmatrix} v_y \\ v_p \end{pmatrix} \quad (3.16)$$

Where $A_{1,1}$ is lower-triangular and $B_{1,1}$ is diagonal so that there is a Wold recursive (causal) ordering among the nonpolicy variables in *y*. Moreover, $A_{2,1}$ is a full matrix so that there is a Wold block-recursive (causal) ordering between nonpolicy and policy variables" (pp.85-86). They further explain that "the core of the [Bernanke-Mihov] analysis focuses on the shape that the matrices $A_{2,2}$ and $B_{2,2}$ must take for the different operating procedures to work properly" (p.86).

Two open economy extensions to the Bernanke-Mihov methodology are provided by De Arcangelis and Di Giorgio (2001) and Fung (2002). The former consider the exchange rate as a nonpolicy variable, but since the contemporaneous reaction of the exchange rate to innovations in the policy variables cannot be excluded, they order it after the policy block. Fung's (2002) semi-structural VAR is simpler, and he models the short run monetary policy behaviour and the foreign exchange market for the analysis of monetary policy in East Asia using the following two equations:

Interest rate: $u_R = v^s + b_{12} v^x$ (3.17)

Exchange rate: $u_X = b_{21} v^s + v^x$ (3.18)

Where $v^x$ and $v^s$ represent the exogenous exchange rate and monetary policy shocks, respectively. Fung shows that "[s]etting $b_{12}$=0, means that the central bank does not contemporaneously respond to the exchange rate shock and the innovations in the interest rate are thus due purely to monetary policy shocks [while] the restriction $b_{21}$=0 […] implies that the innovation in the exchange rate does not respond to the interest rate contemporaneously" (p.4). However, since the policy block has only two variables, this methodology reduces to a recursive VAR when either restriction advocated by Fung is used.

## 3.1 Deriving a Monetary Policy Index

An important by-product of the Bernanke-Mihov methodology is the derivation of a monetary policy index. Arguing that "it is also desirable to have indicators of the overall thrust of policy, including the endogenous or anticipated portion of policy" (p.3), Bernanke and Mihov (1995) use their semi-structural VAR methodology to derive both measures. They show that an overall measure of monetary policy derived using their method is similar to a monetary conditions index "intended to provide assessments of overall tightness or ease, in their day-to-day policy-making" (Bernanke and Mihov (1998), pp.896-897).

Bernanke-Mihov monetary policy index has a simple derivation. From the relationship given in equation (3.15) and the vector of policy variables *P*, the following vector of variables can be obtained

$$A^{-1}(I-G)P \tag{3.19}$$

According to Bernanke and Mihov (1995), these variables, "which are linear combinations of the policy indicators *P*, have the property that their orthogonalized VAR innovations correspond to the structural disturbances *v*. In particular, one of these variables, call it *p*, has the property that its VAR innovations correspond to innovations in the monetary policy shock" (p.13). They propose using the estimated linear combination of policy indicators *p* as a measure of overall monetary policy stance.

Bernanke and Mihov (1998) identify two shortcomings of this measure: "first this indicator is not even approximately continuous over changes in regime […] Second, this measure does not provide a natural metric for thinking about whether policy at a given time is "tight" or "easy"" (p.898). They continue to argue that "a simple transformation of this variable seems to correct both problems. Analogous to the normalization applied to the reserves aggregates in the estimation, to construct a final total policy measure we normalize *p* at each date by subtracting from it a 36-month moving average of its own past values. This has the effects of greatly moderating the incommensurable units problem, as well as defining zero as the benchmark for "normal" monetary policy" (p.898).

## 3.2 Modelling the Policy Block for Sri Lankan Monetary Policy

In the case of Sri Lanka, three time series variables are selected to be included in the policy block. The first is reserve money (RM), which is the operating target for monetary policy in Sri Lanka. The second is the interbank call-money market rate (CR) which is an overnight interest rate closely influenced by the CBSL policy action. The third is the exchange rate (Sri Lankan rupees per SDR) (XRT). The choice of these variables will be discussed in the next section. However, it should be noted that the negative of RM and XRT are used in the model, so that an increase in any variable in the policy block would mean a policy contraction, as explained at a later point in this analysis. Accordingly, a positive sign in front of NXRT would mean an appreciation of the Sri Lankan rupee.

The following three equations explain (in innovation terms) the model used for the present analysis (The derivation is not shown but straight-forward).

$$u^{NRM} = \alpha u^{CR} - \beta u^{NXRT} + \phi^{NRM} v^{d} \tag{3.20}$$

$$u^{NXRT} = \gamma u^{CR} + \phi^{NXRT} v^{e} \quad (3.21)$$

$$u^{CR} = \phi^{d} v^{d} + \phi^{e} v^{e} + v^{s} \quad (3.22)$$

Equation (3.20) shows that the demand for RM is negatively related to CR and positively to an appreciation of the rupee (through its effects on net foreign assets of the CBSL). The structural demand shock is depicted by $v^d$. Equation (3.21) shows that an increase in CR results in an appreciation of the rupee, while $v^e$ represents a structural external shock. Equation (3.22) is the CBSL policy reaction function, and the VAR residual $u^{CR}$ would include the CBSL reaction to structural demand shocks, structural external shocks, as well as structural monetary policy innovations.[3]

Residuals obtained from VAR (u) can then be interpreted as

$$u = A^{-1}Bv \quad (3.27)$$

$$\begin{bmatrix} u^{NRM} \\ u^{NXRT} \\ u^{CR} \end{bmatrix} = \begin{bmatrix} \phi^{NRM} + \phi^{d}(\alpha - \beta\gamma) & -\beta\phi^{NXRT} + (\alpha - \beta\gamma)\phi^{e} & \alpha - \beta\gamma \\ \gamma\phi^{d} & \phi^{NXRT} + \gamma\phi^{e} & \gamma \\ \phi^{d} & \phi^{e} & 1 \end{bmatrix} \begin{bmatrix} v^{d} \\ v^{e} \\ v^{s} \end{bmatrix} \quad (3.36)$$

Furthermore, structural innovations *v*, can be isolated as follows:

$$B^{-1}Au = v \quad (3.44)$$

$$\begin{bmatrix} v^{d} \\ v^{e} \\ v^{s} \end{bmatrix} = \begin{bmatrix} \left(\frac{1}{\phi^{NRM}}\right) & \left(\frac{\beta}{\phi^{NRM}}\right) & -\left(\frac{\alpha}{\phi^{NRM}}\right) \\ 0 & \left(\frac{1}{\phi^{NXRT}}\right) & -\left(\frac{\gamma}{\phi^{NXRT}}\right) \\ -\left(\frac{\phi^{d}}{\phi^{NRM}}\right) & -\left(\frac{\beta\phi^{d}}{\phi^{NRM}} + \frac{\phi^{e}}{\phi^{NXRT}}\right) & \left(\frac{\alpha\phi^{d}}{\phi^{NRM}} + \frac{\gamma\phi^{e}}{\phi^{NXRT}} + 1\right) \end{bmatrix} \begin{bmatrix} u^{NRM} \\ u^{NXRT} \\ u^{CR} \end{bmatrix} \quad (3.51)$$

The model (3.26) is not identified. The number of restrictions required for just-identification on A and B matrices is, according to equation (3.02) is

$$2K^{2} - \frac{K(K+1)}{2} = K^{2} + \frac{K(K-1)}{2}$$

---

[3] Piffanelli (2001), who uses the Bernanke-Mihov methodology, also employs a policy interest rate, exchange rate and money supply in the policy block in her study of monetary policy in Germany.

$$=3^2+\frac{3(3-1)}{2}=9+3=12\,. \qquad (3.55)$$

whereas there are only 11 restrictions. Just identification can be achieved in the following ways by imposing one additional restriction:

i) *Restricted capital account:* This means that the exchange rate does not react to interest rate innovations, i.e.,

$$\gamma=0 \qquad (3.56)$$

Then, the structural shock $v^s$ reduces to,

$$v^s=-\left(\frac{\phi^d}{\phi^{NRM}}\right)u^{NRM}-\left(\frac{\beta\phi^d}{\phi^{NRM}}+\frac{\phi^e}{\phi^{NXRT}}\right)u^{NXRT}+\left(\frac{\alpha\phi^d}{\phi^{NRM}}+1\right)u^{CR} \qquad (3.57)$$

ii) *Fully floating exchange rate regime: This* means that the net foreign assets, which is a part of reserve money remains unchanged, i.e.,

$$\beta=0 \qquad (3.58)$$

Then, the structural innovation becomes

$$v^s=-\left(\frac{\phi^d}{\phi^{NRM}}\right)u^{NRM}-\left(\frac{\phi^e}{\phi^{NXRT}}\right)u^{NXRT}+\left(\frac{\alpha\phi^d}{\phi^{NRM}}+\frac{\gamma\phi^e}{\phi^{NXRT}}+1\right)u^{CR} \qquad (3.59)$$

iii) *Strongin assumption:* Following Strongin (1992), Bernanke and Mihov (1995,1998) assume that reserve money does not react to interest rate innovations contemporaneously, i.e.,

$$\alpha=0 \qquad (3.60)$$

The structural shock then reduces to,

$$v^s=-\left(\frac{\phi^d}{\phi^{NRM}}\right)u^{NRM}-\left(\frac{\beta\phi^d}{\phi^{NRM}}+\frac{\phi^e}{\phi^{NXRT}}\right)u^{NXRT}+\left(\frac{\gamma\phi^e}{\phi^{NXRT}}+1\right)u^{CR} \qquad (3.61)$$

However, the need to identify different targeting regimes would mean that the model may need to be overidentified. Accordingly, the following three targeting regimes are considered:

*i)* *Interest rate targeting:* The imposition of the following two restrictions leads to the model being overidentified by 1 restriction.

$$\phi^d=\phi^e=0 \qquad (3.62)$$

The structural shock then becomes,

$$v^s = u^{CR} \tag{3.64}$$

i.e., the VAR residual $u^{CR}$ represents the structural shock.

ii) *Reserve money targeting:* The imposition of the following three restrictions leads to the model being overidentified by 2 restrictions.

$$\alpha = \beta = 0 \text{ and } \phi^{NRM} = 1 \tag{3.65}$$

Structural innovation $v^s$ then reduces to

$$v^s = -\phi^d u^{NRM} - \left(\frac{\phi^e}{\phi^{NXRT}}\right)u^{NXRT} + \left(\frac{\gamma\phi^e}{\phi^{NXRT}} + 1\right)u^{CR} \tag{3.68}$$

while the innovation to money demand becomes the relevant structural shock.

$$v^d = u^{NRM} \tag{3.71}$$

*iii)* *Exchange rate targeting:* The following restrictions lead to the model being overidentified by one restriction.

$$\gamma = 0 \quad \text{and } \phi^{NXRT} = 1 \tag{3.72}$$

Structural innovation $v^s$ then becomes,

$$v^s = -\left(\frac{\phi^d}{\phi^{NRM}}\right)u^{NRM} - \left(\frac{\beta\phi^d}{\phi^{NRM}} + \phi^e\right)u^{NXRT} + \left(\frac{\alpha\phi^d}{\phi^{NRM}} + 1\right)u^{CR} \tag{3.73}$$

while the external shock $v^e$ becomes the relevant structural shock.

$$v^e = u^{NXRT} \tag{3.76}$$

## 3.3 Deriving a Monetary Policy Index for Sri Lanka

Following equation (3.19), and using the policy block model for Sri Lanka a monetary policy index can be derived as follows:

$$\left(B^{-1}A\right)P$$

$$= \begin{bmatrix} \left(\frac{1}{\phi^{NRM}}\right) & \left(\frac{\beta}{\phi^{NRM}}\right) & -\left(\frac{\alpha}{\phi^{NRM}}\right) \\ 0 & \left(\frac{1}{\phi^{NXRT}}\right) & -\left(\frac{\gamma}{\phi^{NXRT}}\right) \\ -\left(\frac{\phi^{d}}{\phi^{NRM}}\right) & -\left(\frac{\beta\phi^{d}}{\phi^{NRM}} + \frac{\phi^{e}}{\phi^{NXRT}}\right) & \left(\frac{\alpha\phi^{d}}{\phi^{NRM}} + \frac{\gamma\phi^{e}}{\phi^{NXRT}} + 1\right) \end{bmatrix} \begin{bmatrix} NRM \\ NXRT \\ CR \end{bmatrix}$$

$$= -\left(\frac{\phi^{d}}{\phi^{NRM}}\right) NRM - \left(\frac{\beta\phi^{d}}{\phi^{NRM}} + \frac{\phi^{e}}{\phi^{NXRT}}\right) NXRT + \left(\frac{\alpha\phi^{d}}{\phi^{NRM}} + \frac{\gamma\phi^{e}}{\phi^{NXRT}} + 1\right) CR \qquad (3.77)$$

As explained by Bernanke and Mihov (1995, 1998), the monetary policy measure so derived is a linear combination of all variables in the monetary policy block and is a useful index for observing the direction of monetary policy.

## 3.4 Data Description

The main data sources in this analysis are the IMF's International Financial Statistics and the publications of Central Bank of Sri Lanka. Although many data series required are available from 1950s, this study uses data since 1978 in order to focus on the effects of Sri Lanka's monetary policy in an open economy framework.

The key non-policy variables that will be used are real gross domestic product (GDP) and consumer price level (CPI). Similar to the case of other economies as explained earlier, one faces some difficulty in choosing a suitable monetary policy variable in the context of Sri Lanka. Potential monetary policy indicators can be categorised under three broad classes, namely, monetary aggregates, interest rates, or exchange rate.

**Table 1**
**Data Series Used in the Analysis**

| **Series** | **Units** | **Source** | **Remarks** |
|---|---|---|---|
| Gross Domestic Product at 1996 Constant Factor Cost Prices (GDPSA) | Sri Lankan Rupees Million Base year =1996 | CBSL-Annual Reports and GDP Press Releases | Interpolated from Annual series for the period from 1978-1995 and from Quarterly Seasonally adjusted series from 1996-2005 |
| Colombo Consumers' Price Index (CCPISA) | Units: Index No Base year =2000 (=100) | IFS Line 64...ZF CPI:COLOMBO 455 MNUAL WRKRFAM | Seasonally adjusted using Census X-12 ARIMA |

| | | | |
|---|---|---|---|
| SDR Exchange Rate (XRTSDRAVGSA) | Sri Lankan Rupees per SDR | IFS Line ..AA.ZF MARKET RATE | Monthly Average Seasonally adjusted using Census X-12 ARIMA |
| Reserve Money (RMSA) | Sri Lankan Rupees Million | IFS Line 14...ZF RESERVE MONEY | End Period Seasonally adjusted using Census X-12 ARIMA |
| Interbank Call Money Market rate (CALLRTSA) | Percentage points | IFS Line 60B..ZF INTERBANK CALL LOANS | End period Seasonally adjusted using Census X-12 ARIMA |

Of the monetary aggregates, reserve money, which is the operating target of monetary policy implementation and closely monitored by the Central Bank on a weekly basis, is a preferred candidate over the narrow money (M1) or broad money (M2 or M2b) aggregates.

Although the Repo rate and the reverse Repo rate (and earlier the bank rate) are the direct policy instruments, these do not span over the full sample. For instance the active use of the bank rate was discontinued in 1985, while the Repurchase rate was introduced only in 1993. However, the interbank call money market rate, which is not a policy variable *per se*, is an overnight interest rate closely monitored by the Central Bank while its policy actions are swiftly reflected in the changes in this rate. This suggests that the interbank call money market rate could be used as an appropriate indicator of monetary policy.

Finally, since the exchange rate has been a managed float through the most of the sample period, it also has the potential of being used as a monetary policy indicator. Although the exchange rate was floated in 2001, being a small open economy with heavy trade dependency, the exchange rate still attracts much attention in monetary policy discussions, which justify its use as a monetary policy variable in the present analysis. Also, as Fung (2002) states in the context of East Asian economies "[t]he exchange rate channel is one of the key channels of monetary transmission. A contractionary monetary policy leads to an appreciation of the local currency, which in turn will reduce exports and exert downward pressure on inflation. The currency appreciation will also reduce domestic inflation through lower import prices. The more open the economy, the more important the exchange rate channel" (p.2).

All the data series used are monthly. Since a monthly real GDP or aggregate production series is not available, the annual series (and the quarterly series from 1996) is interpolated using the Goldstein and Khan (1976) method.[4] Using monthly series is

[4] Attempts to assess the effects of monetary policy in Sri Lanka face a major drawback as a long time series of high frequency aggregate production is not available. However, several methods exist to derive high frequency (e.g. monthly) data series from available

important since the identifying assumption of there being "no feedback from policy variables to the economy within the period […] or the alternative assumption that policy-makers do not respond to contemporaneous information" cannot be defended if one uses quarterly or annual data. (Bernanke and Mihov (1995), pp.19-20) Also, as IMF (2004) states, "[w]hile the CBSL does not observe GDP contemporaneously (within a quarter) when deciding on interest rates, they do observe variables strongly correlated with it – such as rainfall, government revenue, exports, or industrial production; data on prices and reserve money, which is strongly correlated with broad money, are available with a very short lag" (p.7, n.).

There are two schools of thought as to whether the variables used in the VAR need to be stationary. One school argues against differencing even when the variables are I(1) and against detrending as well. Sims (1988), Sims, Stock, and Watson (1990), Leeper, Sims, and Zha (1996), Bernanke and Mihov (1997), and Bagliano and Favero (1998) belong to this category and argue that differencing throws away valuable information and the standard asymptotic tests are still valid even if the VAR is estimated in levels.

With regard to possible cointegrating relationships Bernanke and Mihov (1997) argue that the "levels specification will yield consistent estimates whether cointegration exists or not, whereas a differences specification is inconsistent if some variables are cointegrated" (p.1037, n.6). Most researchers neglect cointegration constraints "motivated by the following considerations. First, the analysis is generally focused on short-run constraints and the short-run dynamic response of the system. When cointegration constraints are excluded, this only implies that the long-run responses of some variables are not constrained and might follow a divergent path. However, the short-run analysis is still valid" (De Arcangelis and Di Giorgio (2001), p.86 n.11). Not imposing cointegrating relations also allows to "avoid a long-run identification problem, which may be in principle difficult to solve" (Bagliano and Favero (1998)).

The proponents of the other school of thought argue that "the majority view is that the form of the variables in the VAR should mimic the true data generating process. This is particularly true if the aim is to estimate a structural model" (Enders (2004), p.270). Enders shows that if the variables included in the VAR are not cointegrated "it is preferable to use the first differences" and if the VAR is estimated in levels "[t]ests lose power because you estimate $n^2$ more parameters (one extra lag of each variable in each equation)," and "the impulse responses at long forecast horizons are inconsistent estimates of the true responses. Since the impulse responses need not decay, any imprecision in the coefficient estimates will have a permanent effect on the impulse responses. If the VAR is estimated in first differences, the impulse responses decay to zero and so the estimated responses are consistent" (Enders (2004), p.358). Gujarati (2003) also agrees with Enders and advocates differencing if the variables are non-stationary. The price for transforming data by first-differencing is however, as Harvey (1990) notes, the results being not as satisfactory as using levels.

low frequency (e.g. Annual or Quarterly) data series and the method introduced by Goldstein and Khan (1976) is used in the current analysis.

In the present analysis, the latter method is used and appropriate transformations will be used if some variables are found to be non-stationary.

### *Descriptive Statistics and Unit Root Tests*

Unit root tests (which are not shown here) confirm that while the interest rate (CALLRTSA) is stationary at the 5 per cent level of significance, all other variables become stationary only after a log- difference transformation. That is, CALLRTSA is I(0) while the other series under consideration are I(1). Although the I(1) variables may be cointegrated, since the interest rate, which is of primary importance, is I(0) and because estimating long run equilibrium relationships are not the primary objective of the present analysis, CALLRTSA will be used in levels, while the other series are transformed by taking log-differences. [5]

The descriptive statistics of the final data series used in the analysis after required transformations for the full Sample are given in Table 2. The logarithmic difference transformation of GDP, CPI, reserve money, and exchange rate also allow the series to be interpreted as GDP growth, inflation, reserve money growth and exchange rate depreciation in percentage points. Note that none of the series used as well as the results obtained is annualised.

**Table 2**
**Descriptive Statistics of Data Series after Required Transformations**

| | DLGDPSA | DLCCPISA | DLRMSA | DLXRTSDRSA | CALLRTSA |
|---|---|---|---|---|---|
| Mean | 0.0039 | 0.0090 | 0.0115 | 0.0061 | 0.1827 |
| Median | 0.0041 | 0.0089 | 0.0112 | 0.0050 | 0.1636 |
| Maximum | 0.0136 | 0.0808 | 0.0989 | 0.0879 | 0.7988 |
| Minimum | -0.0136 | -0.0357 | -0.1613 | -0.0614 | 0.0785 |
| Std. Dev. | 0.0030 | 0.0121 | 0.0232 | 0.0176 | 0.0835 |
| Observations | 335 | 335 | 335 | 335 | 336 |

Table 2 shows that, on average, GDP has grown by around 0.4 per cent per month, while prices have increased by around 0.9 per cent monthly. As observed by IMF (2004), "[r]eserve money has grown on average by less than broad money as reserve requirements have declined gradually", but broad money growth is "entirely consistent with the quantity theory and a very small decline in the velocity of money" (pp.4-5). Although, the present study covers a longer period than IMF (2004), their observations seem to apply for this study as well. The Sri Lankan rupee has depreciated

[5] Also, as Lütkepohl (2004) notes, cointegration analysis is sometimes used even if the system has both I(1) and I(0) variables "by calling any linear combination that is I(0) a cointegration relation, although this terminology is not in the spirit of the original definition because it can happen that a linear combination of I(0) variables is called a cointegration relation" (p.89).

against SDR by around 0.6 per cent per month, while the call rate has been, on average, around 18 per cent. All variables, perhaps except for GDP growth, show considerable volatility.

## 4. Analysis

This section begins with estimating a series of recursive VAR specifications. The semi-structural VAR methodology explained in section 3 will then be executed and its results will be analysed. Finally, a monetary policy index is derived using the estimated semi-structural VARs.

A clarification is needed with regard to a simple transformation of reserve money growth and exchange rate depreciation series used in the analysis. An increase in the interest rate (CALLRTSA) can be obviously treated as a monetary policy contraction. However, an increase in the exchange rate (DLXRTSDRAVGSA), as defined in the data description in section 3, indicates exchange rate depreciation, while an increase in the series DLRMSA shows a positive money growth. Both exchange rate depreciation and positive money growth have expansionary effects on output and prices. To bring the latter two series in line with the interest rate, they are redefined by inverting. That is, using the negative of reserve money growth (NRM) and the negative of exchange rate depreciation (NXRT), i.e., exchange rate appreciation, would allow increases in all three series in the policy block to be treated as contractionary shocks. These modified series will be used in the analysis hereafter. Note that the modified definitions were also used in the derivation of the model for the policy block in section 3.

### 4.1 Recursive VAR Estimates

The first recursive VAR to analyse is a model with real GDP, inflation, negative of reserve money growth, exchange rate appreciation, and call rate, in that order. The choice of the order indicates that the last three variables, which are generally considered as policy variables in the present analysis are informed contemporaneously by the macroeconomic variables of GDP growth and inflation. Innovations in policy variables do not affect the macroeconomic variables contemporaneously. The recursive structure employed assumes that the call rate is the most endogenous variable since it is affected contemporaneously by the innovations of reserve money and exchange rate but not *vice versa*. The ordering of reserve money and exchange rate cannot be theoretically explained, but a different ordering of these two variables do not affect the results of the analysis significantly.

Lag length selection criteria are considered in determining a suitable number of lags to be included in the specification. Schwartz and Hannan-Quinn criteria select a short lag length of one lag, while Akaike criterion selects seven lags. The likelihood ratio statistic prefers a longer lag length and recommends the selection of 19 lags. Considering these criteria and the fact that the analysis employs monthly series, an interim approach of using 12 lags is utilised.

However, Wald tests of the null hypotheses of the possibility of exclusion reveal that some interim lags within the 12-lagged specification may be unimportant.

Accordingly, only lags 1, 2, 4, 5, 6 and 12 which are significant at standard levels of significance are used in this recursive VAR.

The specification satisfies the stability properties as shown in Figure 4.1, since all inverse roots of the characteristic polynomial lie inside the unit circle as explained by Lütkepohl (1993) among others.

Mainly due to the use of log differences in the analysis, the goodness of fit is affected. In particular, the exchange rate equation has very low adjusted $R^2$ and F-statistics. $R^2$ and F-statistics improve significantly when recursive VARs with the same specification is used in log levels. However, due to the reasons given in section 3, stationary variables are used in the current VAR analysis.

**Table 3 (Summary)**
**Recursive VAR – Full Sample**
**Vector Autoregression Estimates**

Sample (adjusted): 1979M02 2005M12
Included observations: 323 after adjustments

| | DLGDP | DLCCPI | NDLRM | NDLXRTSDR | CALLRT |
|---|---|---|---|---|---|
| R-squared | 0.408577 | 0.175883 | 0.194516 | 0.113073 | 0.676403 |
| Adj. R-squared | 0.347815 | 0.091214 | 0.111761 | 0.021950 | 0.643157 |
| Sum sq. resids | 0.001752 | 0.036481 | 0.141684 | 0.086364 | 0.723303 |
| S.E. equation | 0.002450 | 0.011177 | 0.022028 | 0.017198 | 0.049770 |
| F-statistic | 6.724157 | 2.077289 | 2.350501 | 1.240889 | 20.34525 |
| Log likelihood | 1499.806 | 1009.495 | 790.3701 | 870.3162 | 527.0879 |
| Akaike AIC | -9.094771 | -6.058794 | -4.701982 | -5.197005 | -3.071752 |
| Schwarz SC | -8.732210 | -5.696232 | -4.339421 | -4.834444 | -2.709191 |
| Mean dependent | 0.003795 | 0.008893 | -0.011705 | -0.006109 | 0.186183 |
| S.D. dependent | 0.003033 | 0.011725 | 0.023372 | 0.017390 | 0.083316 |

The impulse responses obtained from the first recursive VAR show that as a result of a one standard deviation shock of the policy rate, the GDP growth rate falls by around 0.02 percentage points each month for about a year with the peak effect in the fifth month following the shock. The peak effect of an interest rate shock on inflation occurs in the third month following the shock with inflation decreasing by around 0.1 percentage points. However, the effect on inflation is short-lived and the reduction in inflation reverses after 6 months. The effect of a positive innovation of interest rate on reserve money is unclear. Although the exchange rate depreciates for about four months following an interest rate increase, it is followed by a continuous appreciation till the $13^{th}$ month by around 0.05 percentage points each month. The increase in the interest rate dies out only gradually indicating further tightening of monetary policy that follows an initial tightening.

A one standard deviation exchange rate appreciation has a positive effect on GDP which is counter-intuitive, but it has a significant effect on reducing inflation, with inflation decreasing by 0.15 percentage points in the third month following the shock. Interest rate responds to a one standard deviation exchange rate appreciation immediately by reducing the interest rate by around 0.75 percentage points for two months.

Innovations in reserve money growth do not show any significant result, perhaps because the inclusion of an interest rate absorbs the predictive power of reserve money.

In respect of accumulated responses, it can be seen that a one standard deviation innovation to the interest rate reduces GDP growth by a total of around 0.2 percentage points within a year and the output growth recovers only gradually. The accumulated negative effect on inflation totals 0.2 percentage points after 6 months, and the accumulated impact remains positive from 9 months onwards. Reserve money increases at first, but the accumulated result is a decline in reserve money. Similarly, following a brief depreciation of the exchange rate, the accumulate effect is a continuous appreciation.

GDP growth remains positive following an exchange rate appreciation, which is a counter-intuitive result. Inflation declines throughout as a result of an appreciation. An exchange rate innovation (appreciation) leads to the interest rate declines for a long period.

Variance decompositions show that own variance is very important with respect to all variables while monetary policy indicators contribute very little in explaining variance of non policy variables. Perhaps the only exception is the call rate variance due to inflation which is about 15 per cent. Following Bernanke and Mihov (1995, 1998) variance decompositions will be largely ignored in the ensuing discussion.

**Table 4.1**
**Recursive VAR-Full Sample**
**Direction of Responses to a Contractionary Interest Rate Shock**

| Variable | Expected | Observed | | |
|---|---|---|---|---|
| | | On Impact | Peak | Accumulated |
| GDP | ↓ | ↓ | ↓(5) | ↓ |
| CPI | ↓ | ↓ | ↓(3), ↑(7) | ↑ |
| NRM | ↑ | ↓ | ↑(6) | ↑ |
| NXRT | ↑ | ↓ | ↑(5) | ↑ |
| IR | ↑ | ↑ | ↑ | ↑ |

**Table 4.2**

**Recursive VAR-Full Sample**
**Direction of Responses to a Contractionary Exchange Rate Shock (Appreciation)**

| Variable | Expected | Observed | | |
|---|---|---|---|---|
| | | On Impact | Peak | Accumulated |
| GDP | ↓ | ↑ | ↑(3) | ↑ |
| CPI | ↓ | ↓ | ↓(2) | ↓ |
| NRM | Ambiguous | ↓ | ↓(3), ↑(13) | ↓ |
| NXRT | ↑ | ↑ | ↑ | ↑ |
| IR | ↓ | ↓ | ↓(1) | ↑ |

**Table 4.3**
**Recursive VAR-Full Sample**
**Direction of Responses to a Contractionary Reserve Money Shock**

| Variable | Expected | Observed | | |
|---|---|---|---|---|
| | | On Impact | Peak | Accumulated |
| GDP | ↓ | ↑ | ↓(6) | ↓ |
| CPI | ↓ | ↓ | ↑(5) | None |
| NRM | ↑ | ↑ | ↑ | ↑ |
| NXRT | None | ↑ | ↓(3) | ↓ |
| IR | ↑ | ↓ | ↑(5) | None |

Notes:
1. Expected column indicates the expected direction at the peak.
2. On impact column indicates the direction of the first available response.
3. In the peak column, the number within parenthesis is the lag of the peak response.
4. Accumulated column indicates the direction of accumulated response after 36 months.

The summary provided in Table 4 assesses the results obtained from the first recursive VAR against expected results. Results are broadly in line with consensus views when an interest rate innovation is considered. However, exchange rate and reserve money innovations provide some puzzling results.

Since the full sample from January 1978 to December 2005 is marked with several important monetary policy changes, the first recursive VAR specification is tested using several sub-samples to see whether results obtained for the full sample change for sub-samples. The determination of sub-samples is as follows:

**Table 5**
**Determination of Sub-samples**

| Sample Period | Reason |
|---|---|
| January 1978-December 2005 | Full sample |

| | |
|---|---|
| January 1978-September 1993 | Period covers from the beginning of the sample up to the introduction of the Repo rate |
| October 1993-December 2000 | Period covers from the introduction of the Repo rate up to the floating of the exchange rate |
| January 2001-December 2005 | Period covers from the floating of the exchange rate up to the end of the sample period |

The sub-samples fail to improve the ambiguous results obtained from the full sample relating to both reserve money and exchange rate, while recent sub-samples are plagued with the perverse seasonality problem caused by the behaviour of the real GDP series. Standard errors of all impulse responses are high, questioning the statistical significance of the findings. However, some common patterns can be observed from the above results. Innovations to the interest rate reduce GDP growth. The response of inflation to an interest rate shock is often positive.[6] The increase in inflation following an interest rate innovation is the price puzzle and the inclusion of crude oil prices does not provide a solution, as in the case of Fung (2002) who finds that "[i]ncluding the commodity price index or US variables in the VARs, however, does not resolve this price puzzle" (pp.7-8) for many East Asian economies.

The relationship between interest rates and exchange rate appreciation is positive, as expected. The persistence of interest rate innovations suggests that the CBSL changes interest rate gradually, and confirms an earlier finding of IMF (2004) for Sri Lanka. Contractionary exchange rate innovations (appreciations) result in increasing GDP growth at all times. This is somewhat surprising given the export-oriented nature of Sri Lanka's economy where one expects an exchange rate appreciation to discourage exports and thereby reduce GDP growth. IMF (2004) also finds that "[a]n unexpected depreciation […] is associated with a significant decline in output, which suggests that such an innovation may be a proxy for some underlying macroeconomic weakness" (p.11). Innovations in reserve money growth do not lead to significant findings, and the reserve money contractions and interest rates often have a negative relationship, giving rise to what Leeper, Sims, and Zha (1996) called the liquidity puzzle. Fung (2002) also finds a similar puzzling result for Korea.

Although the theory dictates that monetary policy does not have a long run impact on GDP, accumulated responses of GDP growth die out only sluggishly in most occasions.

The next section employs the Bernanke-Mihov methodology instead of recursive VAR methodology to assess whether impulse responses generated from structural VARs provide different results to the ones obtained in the present section.

[6] IMF (2004) also finds that in Sri Lanka, "changes in policy interest rate have a significant effect on output but a small impact on inflation. […] Inflation in Sri Lanka is very volatile and the effect of monetary shocks is dwarfed by supply-side shocks, in particular to agricultural production given the large weight of food in the CPI. […] Since the weight of food in the price index is about 2/3, it is not surprising that the link between monetary policy shocks and inflation is weak" (pp.9-11).

## 4.2 Semi Structural VAR estimates

As explained in detail in Sections 2 and 3, recursive VARs generally assume that a good scalar policy variable is available, and obtain impulse responses by ordering the policy variable last. However, the recursive VARs discussed in previous section showed that as in many other economies, in Sri Lanka also there is a vector of potential policy indicators and one may need to assess the impact of all these policy variables on macroeconomic variables simultaneously. Such a requirement can be met by utilising the Bernanke-Mihov methodology as described in the relationships described in equations (3.20) through (3.22) in Section 3. Accordingly, this section estimates the structural VARs for several sub-samples. The estimates of the structural VARs with different identification schemes will then be compared.

### Just Identified Structural VAR (SVAR-JI)

The first Structural VAR that will be estimated is a just-identified specification for the full sample period. As described in Section 3, there are several ways to achieve just-identification, and the restriction $\gamma = 0$ (equation 3.56) which means that the exchange rate does not react to interest rate innovations contemporaneously will be utilised in this analysis.

The analysis of impulse responses shows that GDP growth and inflation decline following a structural interest rate innovation. The reaction of reserve money growth to an interest rate innovation is still ambiguous, although reserve money growth is negative initially. The exchange rate initially depreciates, but is followed by a continuous appreciation as a result of an interest rate shock. An appreciation of the exchange rate (positive innovation), raises GDP growth, while reducing inflation. A contractionary reserve money growth shock also raises GDP growth while reducing inflation in the very short-run.

The results of the impulse response analysis are summarised in Table 6.

**Table 6.1**
**Structural VAR-JI – Full Sample**
**Direction of Responses to a Contractionary Interest Rate Shock**

| Variable | Expected | Observed | | |
|---|---|---|---|---|
| | | On Impact | Peak | Accumulated |
| GDP | ↓ | ↑ | ↓(5) | ↓ |
| CPI | ↓ | ↓ | ↓(3), ↑(7) | ↑ |
| NRM | ↑ | ↑ | ↑(1) | ↑ |
| NXRT | ↑ | ↓ | ↓ (3) | ↑ |
| IR | ↑ | ↑ | ↑ | ↑ |

**Table 6.2**
**Structural VAR-JI – Full Sample**

| Direction of Responses to a Contractionary Exchange Rate Shock (Appreciation) | | | | |
|---|---|---|---|---|
| **Variable** | **Expected** | **Observed** | | |
| | | **On Impact** | **Peak** | **Accumulated** |
| GDP | ↓ | ↑ | ↑(3) | ↑ |
| CPI | ↓ | ↓ | ↓(2) | ↓ |
| NRM | Ambiguous | ↑ | ↓(3) | ↑ |
| NXRT | ↑ | ↑ | ↑ | ↑ |
| IR | ↓ | ↓ | ↓(1) | ↓ |

**Table 6.3**
**Structural VAR-JI – Full Sample**
**Direction of Responses to a Contractionary Reserve Money Shock**

| **Variable** | **Expected** | **Observed** | | |
|---|---|---|---|---|
| | | **On Impact** | **Peak** | **Accumulated** |
| GDP | ↓ | ↑ | ↓(6) | ↓ |
| CPI | ↓ | ↓ | ↑(5) | ↓ |
| NRM | ↑ | ↑ | ↑ | ↑ |
| NXRT | None | ↓ | ↓(3) | ↓ |
| IR | ↑ | ↓ | ↓ (1) | ↓ |

Notes:
1. Expected column indicates the expected direction at the peak.
2. On impact column indicates the direction of the first available response.
3. In the peak column, the number within parenthesis is the lag of the peak response.
4. Accumulated column indicates the direction of accumulated response after 36 months.

The structural VAR results for the sub-sample from January 1978 to September 1993 are comparable with the recursive VAR for the same sub-sample. As a result of a positive interest rate innovation, both GDP growth and inflation increases initially, but inflation starts to fall significantly after nine months for about a further year. Exchange rate appreciates, in general, after an interest rate shock. Following an exchange rate appreciation, GDP growth rises, while inflation falls on impact. Interest rate decreases, while the exchange rate innovation shows no sign of persistence. A negative innovation in reserve money growth has a lagged effect on reducing GDP growth, while inflation starts to decreases four months after the shock. The puzzling result of interest rate falling after a negative reserve money growth is observed again.

As noted earlier, the sub-sample from October 1993 to December 2000 is marked by the volatility of responses with the seasonality effect of GDP. Following an interest rate innovation both GDP growth and inflation fall, although inflation begins to increase seven months after the shock. Exchange rate appreciates while interest rate innovations are less persistent disappearing six months after an innovation. As a result of a contractionary exchange rate shock, GDP growth increases, inflation falls, while interest rate decreases. A contractionary reserve money shock raises GDP growth but inflation initially falls. Interest rate increases as expected, while reserve money shocks are less persistent in this sub-sample.

The sub-sample from January 2001 to December 2005 is also plagued with the seasonality effect. Although innovations to interest rate and reserve money cause expected negative result on GDP growth, exchange rate shocks continue to affect GDP growth positively. Interest rate innovations do not help reduce inflation. Exchange rate appreciates following an interest rate shock, while the CBSL appears to have changed interest rates gradually, both in terms of magnitude and length of adjustment. Another significant result is that interest rate rises following a negative innovation in reserve money growth similar to the previous sub-sample.

## 4.3 General Discussion on Structural VAR Results

The results obtained from the just-identified structural VARs are not quite different to the results of recursive VARs. The only puzzle that is resolved is the liquidity puzzle, since in two sub-samples interest rate rises following a contractionary reserve money shock. Monetary policy still appears to have little impact on reining-in inflationary pressures while exchange rate appreciation has a counter-intuitive positive impact on GDP growth.

A logical next-step is to test whether the various sub-samples can be identified as different targeting regimes. Accordingly, restrictions $\phi^d = \phi^e = 0$ given in equation (3.62) is used to derive estimates under an interest rate targeting regime, restrictions $\alpha = \beta = 0$ and $\phi^{NRM} = 1$ as in equation (3.65) are utilised to obtain estimates under a reserve money targeting regime. An exchange rate targeting regime is defined by $\gamma = 0$ and $\phi^{NXRT} = 1$ as in equation (3.72). A summary of the results obtained are provided in Table 7.

A comparison of the parameter estimates shows that parameters are broadly consistent within each sample. Also, most parameters carry the expected sign. Parameter $\alpha$ from equation (3.20) is the elasticity of (negative) of reserve money growth to interest rate and is expected to have a positive sign. For the full sample as well as all sub-samples this is estimated to be positive. It is also observed that for the sub-sample from January 2001 to December 2005, this parameter is significantly higher than in other sub-samples. Parameter $\beta$, which is the elasticity of (negative of) reserve money growth to an exchange rate appreciation, does not carry the expected negative sign for the two sub-samples from October 1993 to December 2000, and January 2001 to December 2005. However, through all samples parameter $\beta$ is statistically insignificant. Parameter $\gamma$ shows the effect of interest rate on the exchange rate. This parameter has the expected positive values in all estimates and in the most recent sub-sample has a large and significant value perhaps indicating the impact of the gradual capital account liberalisation that has been taking place in recent times. Parameters $\phi^{NRM}$ and $\phi^{NXRT}$, which show the reaction of (negative of) reserve money and exchange rate to demand

and external shocks, respectively, have positive signs as expected. Parameters $\phi^d$ and $\phi^e$, which show the reaction of the interest rate to demand innovations and external shock, respectively, change signs throughout samples displaying that interest rates have reacted differently to shocks at different times. The analysis of overidentifying restrictions proves futile since all overidentifying restrictions are rejected by the model,[7] possibly indicating that any sub-sample in the post-1978 monetary history of Sri Lanka cannot be identified with one targeting regime. The CBSL has paid attention to all three policy variables included in the model in the conduct of monetary policy and VAR estimates using different identification schemes are unlikely to improve the results obtained from the just-identified models any further.

**Table 7**
**Parameter Estimates for All Structural VAR Models**

| Sample | Model | $\alpha$ | $\beta$ | $\gamma$ | $\phi^{NRM}$ | $\phi^{NXRT}$ | $\phi^d$ | $\phi^e$ | Log likelihood |
|---|---|---|---|---|---|---|---|---|---|
| 1979M02 -2005M12 (Full Sample) | JI-1 | 0.0454 [0.9978] | -0.0993 [0.9908] | 0 | 0.0217 [0.0000] | 0.0171 [0.0000] | 0.0000 [1.0000] | -0.0090 [0.8719] | 3814.6 |
| | IRT | 0.0466 [0.0000] | -0.0988 [0.1683] | 0.0625 [0.0000] | 0.0217 [0.0000] | 0.0168 [0.0000] | 0 | 0 | 3820.0 |
| | RMT | 0 | 0 | 0.0608 [0.0323] | 1 | 0.0168 [0.0000] | -0.0330 [0.5537] | 0.0000 [1.0000] | 2744.0 |
| | XRTT | 0.0456 [0.9833] | -0.0973 [0.9315] | 0 | 0.0217 [0.0000] | 1 | 0.0004 [1.0000] | -0.5207 [0.0000] | 2661.9 |
| 1979M02 -1993M09 | JI-1 | 0.0470 [0.9846] | -0.0232 [0.9795] | 0 | 0.0180 [0.0000] | 0.0175 [0.0000] | -0.0004 [1.0000] | -0.0065 [0.9317] | 2234.8 |
| | IRT | 0.0547 [0.0000] | -0.0212 [0.7870] | 0.0767 [0.0000] | 0.0180 [0.0000] | 0.0173 [0.0000] | 0 | 0 | 2237.3 |
| | RMT | 0 | 0 | 0.0647 [0.0653] | 1 | 0.0173 [0.0000] | 0.0371 [0.6224] | -0.0006 [0.9998] | 1618.4 |
| | XRTT | 0.0514 [0.9908] | -0.0214 [0.9896] | 0 | 0.0180 [0.0000] | 1 | 0.0002 [1.0000] | -0.3686 [0.0000] | 1611.0 |
| 1993M10 -2000M12 | JI-1 | 0.0745 [0.9907] | 0.0054 [0.9996] | 0 | 0.0298 [0.0000] | 0.0135 [0.0000] | 0.0004 [0.0000] | -0.0248 [0.8170] | 1007.0 |
| | IRT | 0.0720 [0.0000] | 0.0010 [0.9969] | 0.0608 [0.0000] | 0.0298 [0.0000] | 0.0128 [0.0000] | 0 | 0 | 1012.1 |
| | RMT | 0 | 0 | 0.0610 [0.0000] | 1 | 0.0128 [0.0000] | -0.3329 [0.0019] | 0.0000 [1.0000] | 749.9 |
| | XRTT | 0.0719 [0.9973] | 0.0054 [0.9999] | 0 | 0.0298 [0.0000] | 1 | 0.0001 [1.0000] | -1.7576 [0.0000] | 676.2 |
| 2001M01 -2005M12 | JI-1 | 0.1398 [0.9359] | 0.0529 [0.7585] | 0 | 0.0163 [0.0000] | 0.0196 [0.0000] | -0.0009 [1.0000] | -0.0015 [0.9906] | 705.7 |
| | IRT | 0.3240 [0.0000] | 0.0732 [0.5020] | 0.4400 [0.0000] | 0.0162 [0.0000] | 0.0192 [0.0000] | 0 | 0 | 707.4 |
| | RMT | 0 | 0 | 0.1034 [0.4288] | 1 | 0.0194 [0.0000] | -0.0192 [0.8819] | -0.0008 [0.9999] | 489.2 |
| | XRTT | 0.1428 [0.9433] | 0.0523 [0.7385] | 0 | 0.0163 [0.0000] | 1 | -0.0007 [1.0000] | -0.0780 [0.5457] | 499.8 |

Note: P-values are in parentheses

[7] Bernanke and Mihov (1995) advocates that since tests for overidentifying restrictions "gives only the statistical, and not economic, significance of model rejections…an alternative strategy is to […] get just-identification; and then, conditional on that restriction, to observe how closely the estimated parameter values of the more general model correspond to those assumed by the more restricted models" (p.26), as performed in the current analysis.

### 4.4 Estimating the Monetary Policy Index

Using the methodology explained in Section 3 and based on equation (3.77), an attempt is made to derive a monetary policy index for Sri Lanka. Although many authors, including Bernanke and Mihov (1995, 1998), and Kasa and Popper (1997) have used the parameter estimates from the just-identified model for the full sample to derive such an index, in this analysis, it is proposed to use an average of parameter estimates (ignoring restricted values) to derive the index. Although, parameter estimates are roughly equal within a sample as already mentioned, taking average values further helps to avoid estimating an index biased toward any particular identifying assumption. The average parameter values for the full sample are as follows:

**Table 8**
**Parameter Values used for the Monetary Policy Index**

| | |
|---|---|
| $\alpha$ | 0.0459 |
| $\beta$ | -0.0985 |
| $\gamma$ | 0.0616 |
| $\phi^{NRM}$ | 0.2170 |
| $\phi^{NXRT}$ | 0.0169 |
| $\phi^{d}$ | -0.0109 |
| $\phi^{e}$ | -0.1766 |

The estimated monetary policy index is displayed in Figure 1. As suggested by Bernanke and Mihov (1995), policy variables are transformed by subtracting them from their own 36-month moving averages before estimating the monetary policy index given by equation (3.77). The estimated parameter values determine the weight on each policy variable, and as expected from the foregoing impulse response analyses, the interest rate has a greater weight than reserve money and the exchange rate. This makes the three policy variables to have comparable units and defined the zero line as "normal" monetary policy.[8] When the index is above the zero line, it can be interpreted as a contractionary monetary policy stance, and vice versa.

[8] Bernanke and Mihov warn that the index defines "normal" monetary policy compared with the recent past. Kasa and Popper (1997) concur: "since only second moments are being used here, these plots cannot say anything about the stance of policy in some absolute sense. Only the stance of policy relative to the historical average is identified" (p.291 n.26).

**Figure 1**
**Monetary Policy Index for Sri Lanka**

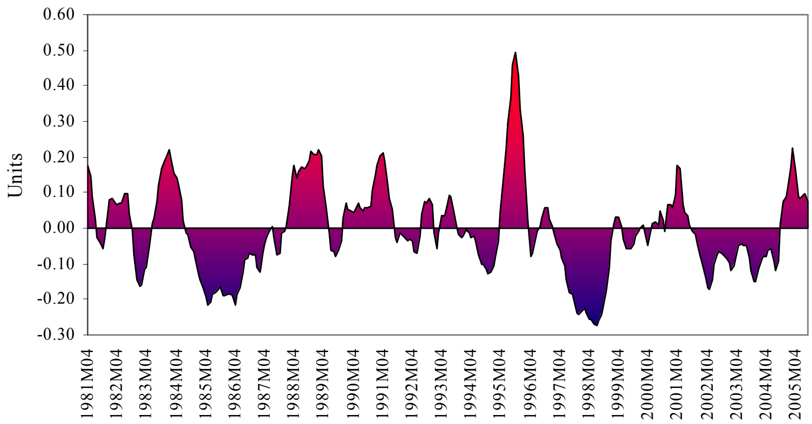
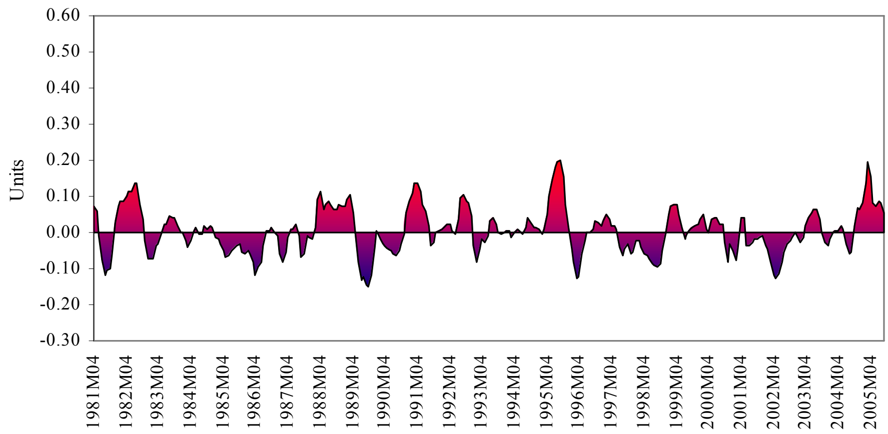


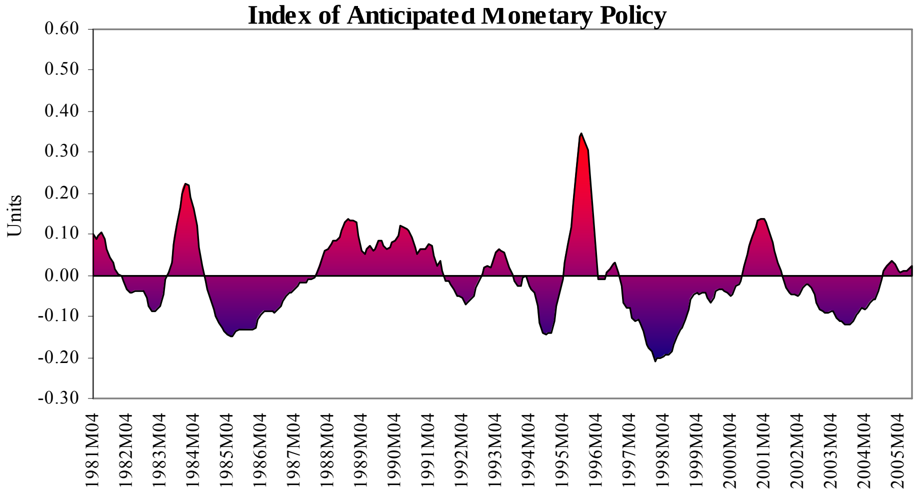

Figure 2 plots the estimated structural monetary policy shocks ($v^s$) obtained from the model with a similar transformation to make it comparable with Figure 1. Structural monetary policy shocks can be defined as the unanticipated monetary policy. According to Kasa and Popper (1997) who estimate a similar index for Japan, [t]he overall stance reflects both endogenous responses to economic conditions and unanticipated changes in the stance of policy" (p. 291). Similar to their observation for Japan, in Sri Lanka also the unanticipated component of monetary policy is relatively small compared with the overall stance of monetary policy. Kasa and Popper, interpret this observation as indicating "that the recent, striking changes in the stance of Japanese monetary policy took place largely in response to the prevailing economic condition" (p.292). This interpretation is applicable to Sri Lanka as well. For instance, even the high interest rate regime observed during the late 1995, it has largely been in response to the existing economic situation of the country.

**Figure 2**
**Estimated Structural Monetary Policy Shocks (Unanticipated)**




The difference between the monetary policy index and exogenous shocks provides the endogenous responses of monetary policy to the current economic condition, and are presented in Figure 3.

**Figure 3**
**Index of Anticipated Monetary Policy**




There are several potential uses for such a monetary policy index. As Bernanke and Mihov (1995) argue, this "total measure of policy stance is potentially useful for evaluating the overall direction of policy, and for making comparisons of current policy stance with policies chosen under similar circumstances in the past" (p.13). The index could be used as scalar measure of composite monetary policy index in future econometric analysis as well. The measure estimated in the present analysis is closer to the monetary conditions index because it comprises the exchange rate in addition to the two monetary indicators of reserve money and interest rate.

Although a detailed analysis using the monetary policy index derived above is not undertaken in the present study, it may be worthwhile to analyse the correlations of GDP growth and inflation (6-month centred moving averages) with the index and its components, as presented in Figure 4.

**Figure 4**
**Dynamic Correlations between the Monetary Policy Index and Macroeconomic Variables**

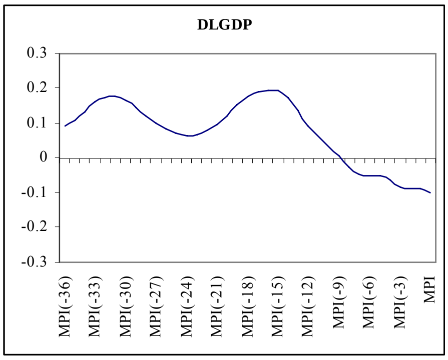



**Figure 4.1.1**

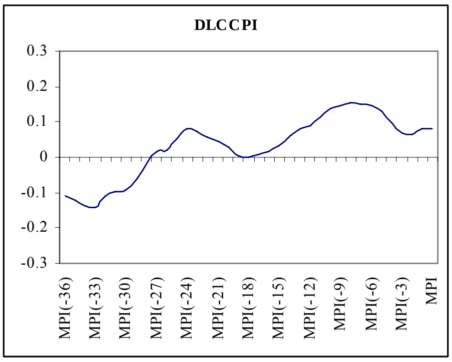



**Figure 4.2.1**

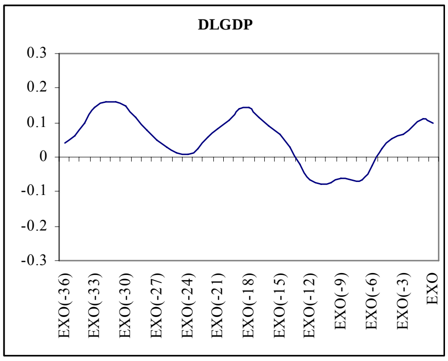



**Figure 4.1.2**

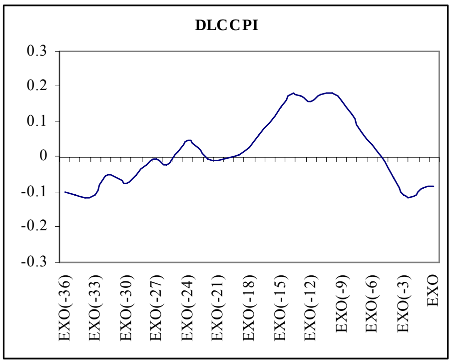



**Figure 4.2.2**

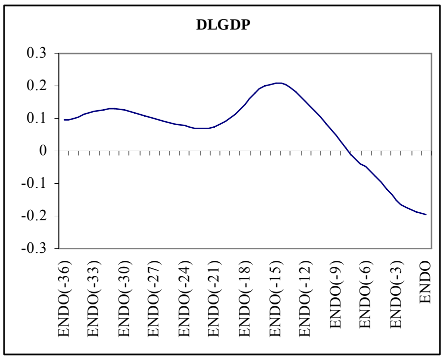



**Figure 4.1.3**

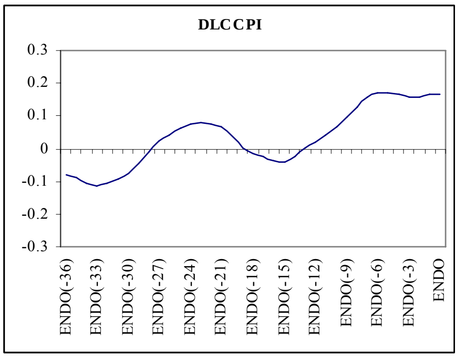



**Figure 4.2.3**

As stated earlier, simple correlations do not provide an ultimate proof of causation, although they can lend support to possible causal relations. Bearing this in mind, the dynamic correlations shown in Figure 4 can be interpreted as follows: contractionary monetary policy has a negative impact on GDP growth with a short-lag from about 9 months; GDP growth is affected mainly by anticipated (endogenous) monetary policy. Agents adjust their economic activity expecting the CBSL to take policy action to address economic conditions; Inflation responds to contractions in both exogenous and endogenous components of monetary policy with a longer-lag of about 28 to 36 months. Unanticipated monetary contractions are also negatively correlated with inflation in the short-run.

Bernanke and Mihov (1995, 1998) compare the index derived using this method with the existing monetary policy measures such as the Romer and Romer dates and the Boschen and Mills index. However, in the context of Sri Lanka, no alternative measure is available, and illustrates the need for further research in this direction.

## 5. Summary and Conclusions

With the aim of analysing the effects of monetary policy on key macroeconomic variables in Sri Lanka, this paper employed methods which can be broadly categorised as structural vector autoregressions. Section 1 discussed the established findings on the relationships between monetary policy and macroeconomic variables, and also provided a brief introduction to Sri Lanka's monetary policy framework. Section 2 reviewed the literature with regard to estimating the effects of monetary policy on macroeconomic variables, and discussed in detail, the vector autoregressive approach to monetary policy. Section 3 formally defined the objective of the present analysis, explained the Bernanke-Mihov methodology and described the data used in the analysis. Section 4 presented the results of the analysis. In this Section, a summary of key findings and limitations and possible future extensions will be discussed.

## 5.1 Summary of Key Findings

Similar to most other economies, in Sri Lanka also, there is a multitude of variables that characterise the monetary policy stance at any given time. The present study analysed the results of a series of recursive VARs for various sample periods and observed that the results are broadly in line with the established empirical findings, especially when the interest rate is considered the monetary policy variable. Following a positive innovation in interest rate, the GDP growth and inflation decreases while the exchange rate appreciates. When money growth and exchange rate are used as policy indicators, the impact on GDP growth contrasts with the established findings. However, as expected, an exchange rate appreciation has an immediate impact on the reduction of inflation. Interest rate innovations are persistent supporting the view that the monetary authority adjusts interest rates gradually, while innovations in money growth and exchange rate appreciation are not persistent. Several puzzling results emerge from the study: for most sub-samples, inflation does not decline following a contractionary policy shock, possibly due to the longer lag effect; innovations to money growth raises the interest rate; when inflation does respond, it reacts to monetary innovations faster than GDP growth does; and, exchange rate appreciations almost always lead to an increase in GDP growth. Results obtained from the Bernanke-Mihov semi-structural VARs, which consider the predictive ability of reserve money, exchange rate and interest rate as monetary policy indicators simultaneously, do not significantly change the impulse responses. However, it was observed that no sub-sample can be considered as purely an interest rate targeting regime, a reserve money targeting regime or an exchange rate targeting regime. The monetary policy index derived using an extension of the Bernanke-Mihov approach revealed results similar to other economies; the behaviour of policy indicators can be explained as a combination of both anticipated an unanticipated monetary policy. Unanticipated monetary policy is relatively a small portion of the overall monetary policy stance, while anticipated monetary policy, i.e., the CBSL's reaction to economic developments explains a large part of monetary policy action. It was also observed that anticipated monetary policy contractions are negatively correlated with GDP growth with a lag of 0-9 months, while both anticipated and unanticipated monetary policy contractions are negatively correlated with inflation with a lag of 28-36 months. The monetary policy index derived can be used in future research as a combined measure of monetary policy or to compare findings of similar indices obtained from different approaches to analyse Sri Lanka's monetary policy in the future.

## 5.2 Limitations of the Study

Several limitations could be identified in this analysis. As noted earlier, the test statistics do not display statistical significance, mainly as a result of the log-differencing of the non-stationary data. Although results improve significantly when log-level series are used, following Enders (2004) and Gujarati (2003), this approach was not taken. It will be interesting to perform the complete analysis using log-levels to see how the results change. Other possible reasons for the lack of significance could be misspecification of the VARs and the existence of important omitted variables.

A number of problems with data series was identified. Reserve money and call money market rate series were as at end-period (end of the month), and using monthly averages may have some impact on estimated results. End-period observations are not necessarily random observations, and this problem could worsen if one used quarterly data. Monthly data for GDP was not available, and the annual (later quarterly) GDP series had to be interpolated. As noted earlier, quarterly GDP series for Sri Lanka is plagued with seasonality which cannot be captured using traditional deseasonalisation methods, and has a perverse impact on econometric estimates. The exchange rate used in this analysis was the nominal exchange rate, and the results may change if the real exchange rate was used. However, the CBSL commenced computing the real exchange rate only in the 1990s, indicating that it was perhaps more interested in the movements in nominal exchange rate. Also, the interest rate used was not a policy rate *per se,* but a closely related short-term money market rate. At least for the recent sample periods, it will be useful to see whether the results change if the policy interest rates are used instead.

Possibly, a major omitted variable in the analysis is an indicator of government finance. Having a high budget deficit and a high debt/GDP ratio, public finance is an important issue in Sri Lanka and the conduct of monetary policy cannot be analysed in isolation. However, in the present analysis, any discussion of government finance was totally avoided for simplicity. The inclusion of an indicator of public finance may help to solve some puzzling results and also explain why the international crude oil price does not have a significant impact on the variables included in the present analysis. Specifically, in Sri Lanka, prices of petroleum products are administered given their impact on GDP growth and inflation, and oil price shock are absorbed largely by the government budget, at least in the short-run.

Being a VAR analysis, the current study focused mainly on residuals or innovations rather than on monetary policy rules. A different model is needed if one is to analyse monetary policy rules for Sri Lanka.

The policy block used in this analysis contained only three variables, namely, reserve money, exchange rate and interest rate. Other potential candidates for the policy block are the international reserve (net foreign assets of the CBSL), the interest rate corridor and the reserve requirement.

Although a monetary policy index was derived using the Bernanke-Mihov methodology, unlike in the USA, in Sri Lanka there are no other indicators of monetary policy. As noted earlier, the development of other indicators will allow a comparison of the performance of these indicators.

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