S S (DEAP) : 2 / 2010

RBI STAFF STUDIES

MONETARY POLICY BEHAVIOUR IN INDIA: EVIDENCE FROM TAYLOR-TYPE POLICY FRAMEWORKS

Bhupal Singh

DEPARTMENT OF ECONOMIC ANALYSIS & POLICY

APRIL 2010

MONETARY POLICY BEHAVIOUR IN INDIA: EVIDENCE FROM TAYLOR-TYPE POLICY FRAMEWORKS

Bhupal Singh*

This paper seeks to characterise the monetary policy behaviar in India in the framework of Taylor-type rules. Notwithstanding the measurement issues, an array of estimated rules indicate that while the monetary policy appeared more responsive to the output gap than to the inflation gap during the period 1950-51 to 1987-88, there is a shift in policy response during the period 1988-89 to 2008-09 with relatively strong reaction to inflation gap than to the output gap. The evidence suggests more than proportional response of monetary policy to inflation gap in the latter period. The size of coefficient of inflation gap has also increased significantly over time, suggesting a shift in the emphasis of monetary policy towards inflation concerns. The interest rate smoothing behaviour of the central bank has also changed from a high degree of smoothing in the earlier period to gradual adjustment of interest rates in the latter period. The estimates from a structural VAR framework also firmly establish that variations in the short-term interest rates are driven more by the inflation gap than the output gap.

Introduction

An important question often raised is what should be the optimal monetary policy? The optimality is to be seen in the context of the goals of monetary policy. The ultimate goal of monetary policy is recognised to be maximisation of welfare, which in turn can be visualised in terms of maintaining low and stable inflation and stabilising the "welfare relevant

* Author is Assistant Adviser in the Department of Economic Analysis and Policy, Reserve Bank of India, Mumbai. The views expressed in the paper are those of the author and do not represent the views of the Reserve Bank of India. The author was benefited from the discussion held with Ole Rummel of the Centre for Central Banking Studies of the Bank of England on the methodological aspects in estimating the monetary policy rules. The author is grateful to Abhilasha for useful suggestions and Jayalakshmi for painstaking proof readings of the paper.

output gap" (Blanchard, 2006).[1] In the standard new Keynesian framework that has dominated the conduct of monetary policy in the recent decades, stabilising inflation also minimises the distance of output from the welfare maximising output. In achieving such stabilisation, monetary policy frameworks have been dominated over the period from Keynesian to monetarism to New-Classical and New-Keynesian orthodoxy. In the spirit of the New-Keynesian belief, Taylor (1993) demonstrated that a simple reaction function relating Fed's policy instrument (short-term policy interest rate) to an inflation gap and output gap was able to capture the actual path of the federal funds rate or the behaviour of the monetary policy. In other words, such simple policy rule adjusts the policy instruments to observed deviations of policy objectives from target or trend. These are also called as monetary policy feedback rules as there is a policy instrument feedback in response to macroeconomic outcomes.[2] This rule-based characterisation of monetary policy by Taylor in 1993 compared the Federal Reserve's actual path of interest rate over the period 1987 to 1992 with the interest rate path suggested by the rule and revealed a close correspondence between the two. This important contribution to monetary theory had been shaped by the insight of the observed behaviour of the monetary policy makers. It subsequently opened new vistas for monetary policy theory and practice and provided launching pad for exploring the behaviour of other central banks and relative performance of simple policy rules and optimal rules. The Taylor rule, therefore, attempted to answer the basic operational question of how should a central bank decide what is the right interest rate to set at any point of time? The usefulness of Taylor rule for a central bank lies in the fact that estimated reaction functions exemplify how, given macroeconomic conditions, interest rates were set in the past, which may serve key input for future policy formulations. Similarly, reaction functions are relevant because they capture

1 Blanchard (2006) argues that the role of monetary policy is maximisation of welfare rather than simply the control and stabilisation of inflation.

2 Monetary policy rules date back to the gold standard. A well-known example of a particularly simple rule is Friedman's (1959) k% rule, a proposal to keep money growth to a fixed percentage each period. The McCallum rule for setting the monetary policy instrument derives the nominal growth of base money consistent with delivering a nominal GDP target (McCallum, 1988).

the main considerations underlying a central bank's interest rate setting behaviour.

A large part of the discussion of monetary policy on the Taylor rule relates to how the policy should be conducted or how far the actual conduct of the policy deviated from the rule-based parameters. The Taylor rule type policy framework was effective in fighting the inflationary booms of the 1970s. The current global financial crisis has also highlighted that sustained deviations from the Taylor rule by the monetary authorities could have given rise to excessive expansion in real activity. It is argued that accommodative monetary policies after the recession of the early 2000s maintained policy rates for too long below the level that would have been produced from a simple rule specifying a reaction to an output gap and inflation (Taylor, 2007; 2008). This implies that if monetary policies had not deviated from rule-based criteria, the excessive rise in asset prices and hence the impact of present global crisis would have been contained.[3]

Even if central banks are not adhering to predetermined rules in conducting monetary policies, an analysis of what a rule-based monetary policy would entail can serve as a valuable guidance in the exercise of discretion.[4] It is in the backdrop of the above debate, we attempt to examine the relevance of such policy rules in India. However, the issue is not straightforward in the Indian case as the monetary policy operating framework has experienced significant shifts in terms of principal operating policy instruments from reserve requirements to interest rate. Given the structural issues in the financial markets and challenges in transmission of policy interest rates to other interest rates in the financial system, both quantitative as well as interest rate channels are used optimally, although the interest rate signals seem to have emerged more

3 Others, however, argue that focus of the most monetary policy framework on inflation and output stability were based on a too narrow approach to macroeconomic stability. This school of thought advocates for central bank to lean against the unsustainable asset price rises and financial instability, even at the cost of some more variability in inflation and output (see Borio and Lowe, 2002, 2004; White, 2006).

4 Even if central banks are not following an explicit rule, the choice of a level of intermediate target amounts to a rule following behaviour for central banks.

significant in the post-liberalisation period. The challenges in estimating such rule-based benchmarks also arise due to measurement of potential output as it cannot be observed. Nevertheless, such simple policy rules can provide important benchmark for the evaluation of the demand management policies.

We attempt to discuss theoretical foundations of such policy rules, the advantages in deriving such implicit rule-based path of the monetary policy, challenges in measurement and how the simple monetary policy rules proposed in the literature provide a reasonable characterisation of the monetary policy in India. Section II of the paper deals with the theoretical paradigms of monetary policy and the evolution of the Taylor Rule. The issues in the measurement of inflation and output gap and the relevance of the Taylor rule in the Indian context are discussed in Section III. Section IV analyses the relative weights of inflation and output in the formulation of monetary policy reaction function and Section V develops a small structural VAR model to assess the dynamic interaction of inflation, output gap and monetary policy. Section VI concludes.

Section II

Theoretical Framework of the Monetary Policy Rules

The debate whether monetary policy should be conducted following certain predetermined rules or should exercise discretion, has been unsettled. Wicksell (1898) put forth the simple reactive monetary policy rule, "If the price rises, the interest rate should be raised; and if the price falls, the interest rate should be cut..." The intellectual discourse in monetary policy was also strongly influenced by the classic Tinbergen (1952) and Theil (1964) policy framework in which each policy instrument is geared to meet a defined objective.[5] While price stability and output stabilisation are final objectives of monetary policy, they are not directly under the control of the central bank. Monetary authorities typically set intermediate targets in terms of macroeconomic variables, which bear a stable relationship with the overall objectives of monetary policy.

[5] The theoretical paradigm introduced by Jan Tinbergen and Henri Theil suggested that the achievement of more than one policy objective requires the implementation of more than one policy instrument.

During the 1960s and 1970s, the Phillips curve paradigm came to dominate monetary policy framework, which believed that there exists not only a short-run but even a long-run trade-off between inflation and output. This led to the belief that central banks could achieve higher growth on a sustainable basis, if they could tolerate higher inflation. The pitfalls of this reasoning were brought out by the stagflation of the 1970s. In the aftermath of the breakdown of Bretton Woods system of fixed exchange rate and the boom-bust cycles, a consensus emerged in macroeconomics that was based on the premise that macroeconomic stability could be achieved through interest rate. It was argued that an independent central bank entrusted with the responsibility to modulate interest rate, with its commitment to low and stable inflation, would anchor inflation expectations in the economy.[6] This also deemphasised the role of fiscal policy as a stabilisation tool and perceived regulation to achieve fair markets and resilient financial system as a microeconomic tool. The ineffectiveness of interest rate in tackling the inflationary pressures of the 1970s, however, led to revival of interest in monetary targeting in the 1980s, evident in the Volcker era at the Federal Reserve.

During the late 1980s, these paradigms started to change following globalisation, technological advancements and large movement of capital across national boundaries. In view of difficulties in conducting monetary policy with explicit intermediate targets, central banks started switching to direct inflation targeting. Thus, a dominant view in monetary economics that emerged was central banks should be guided by the output and inflation gap in conducting monetary policy or interest rate setting – the popularly known Taylor rule (Taylor, 1993). Taylor rule for the conduct of monetary policy has attracted greater attention in the recent period with the apparent breakdown of the relationship between money growth and inflation (Blinder, 2006). The advantage of this rule was that it expressed a complicated phenomenon of monetary policy reaction function in very simple terms.[7] This simple benchmark rule of monetary policy has been

---

6 Goodfriend (2003) argued that monetary policy can best encourage employment and economic growth in the long run by stabilizing inflation and inflation expectations.

7 McCallum (1999) observed that Taylor explained monetary rules with brilliant simplicity that it made the rules more palatable to central bankers, especially as he demonstrated that US monetary policy could be explained very closely by his formula.

useful in assessing the monetary policy stance in the advanced economies, however, less examined in developing economies due to a number of factors such as measurement issues and framework for the conduct of monetary policy. Nevertheless, the actual conduct of monetary policy in many economies, whether inflation targeting or non-inflation targeting, has been observed to be implicitly guided by some sort of benchmark relating to inflation and output gap, if not the strictly well defined policy rules.

Such rules or policy reaction functions, as they are euphemistically termed, reduce the inflation bias in growth oriented monetary policy (Svensson, 1999a). An increasing number of central banks in advanced economies as well as EMEs emphasise the role of short-term interest rates as operating targets of monetary policy or as an instrument variable or as a key information variable (Friedman, 2000). The reaction function of central banks that have adopted interest rates as instruments of monetary policy can be encapsulated in the Taylor rule. A Taylor-rule relates short-term policy interest rates to deviations of inflation and output from their target and potential, respectively. In particular, the Taylor principle requires that nominal interest rates should increase more than one-to-one with an increase in inflation rate so that real interest rates also rise in order to dampen aggregate demand and bring inflation back to target (Clarida, Gali and Gertler, 2000). It stipulates how much the central bank would or should change the nominal interest rate in response to divergences of actual inflation rates from target inflation rates and of actual gross domestic product (GDP) from potential GDP. The rule can be written as follows:

$$i_t^* = \pi_t + r_t^* + \phi(\pi_t - \pi_t^*) + \gamma y_t \qquad (1)$$

In this equation, i_t is the target short-term nominal interest rate (*e.g.* the federal funds rate in the US), π_t is the rate of inflation as measured by the GDP deflator, π_t^* is the desired rate of inflation, r_t^* is the assumed equilibrium real interest rate, y_t is the output gap, *i.e.* real GDP minus the potential output. (Y_t – Y) Equation (1) can be rewritten as:

$$i_t^* = \mu + \lambda\pi_t + \gamma y_t \qquad (2)$$

where, $\mu = r_t^* - \phi\pi_t^*$ and $\lambda = 1 + \phi$. According to the rule, both π_t and ϕ should be positive (as a rough rule of thumb, Taylor's 1993 paper proposed setting $\phi = \gamma = 0.5$). The rule recommends a relatively high interest rate (tight monetary policy) when inflation is above its target or when output is above its full-employment level, in order to reduce inflationary pressure. It recommends a relatively low interest rate (easy monetary policy) in the opposite situation, to stimulate output. By specifying $\phi>0$, Taylor rule says that an increase in inflation by one percentage point should prompt the central bank to raise the nominal interest rate by more than one percentage point (i.e., $1 + \phi$, the sum of the two coefficients on π_t in equation (1). The real interest rate is (approximately) the nominal interest rate minus inflation, stipulating $\phi>0$. The real interest rate prevailing in the economy, when both output and inflation are on the targeted trajectory, would be determined by π_t.

Use of such rule-based criteria in conducting monetary policy include systematically fostering price stability and full employment in reducing uncertainty and increasing credibility of future actions by the central bank. It may also help avoid the inefficiencies of time inconsistency which arise due to the exercise of discretionary policy. Svensson (2007) explains that the impact of monetary policy on output and inflation depends on the decisions of the private sector it induces relating to prices and output. These private sector decisions are guided by their expectations of inflation, output and interest rate that monetary policy induces. In fact, private sector decisions are importantly guided by the expected future monetary policy stance rather than the current interest rate.

In the actual conduct of monetary policy, the recommendations based on the Taylor principle still do not seem to be unambiguously found useful for the policy conduct as significant variations in the recommendations may emanate from marginal changes in the underlying specifications.[8] If the rule recommendations based on alternative measures of output and inflation yield

[8] Svensson (2003) and Woodford (2001) suggest that commitment to simple policy rules may not always be optimal for the conduct of monetary policy.

significantly different outcomes, they may compromise their usefulness. Although there is agreement that adherence to such policy rules help stabilise output in the short run and achieve a low rate of inflation, there is still less unanimity about the coefficients. What weight the central banks assign to inflation and output gaps? The answer would depend upon the preferences of central banks and their legal mandates. The theoretical guidance for such a preference function is visualised in the form of a loss function of the following form that central banks want to minimise:[9]

$$L_t = [\pi_t - \pi^*]^2 + \lambda[y_t - y^*]^2 \tag{3}$$

Thus, different central banks may have different values for λ. The central banks with high aversion to inflation volatility would attempt to maintain a low value for λ and those with a high aversion to output or employment volatility would react more strongly to the output gap and endeavour to keep λ at a high level. Thus, a lack of unanimity about the optimal parameter values seems to be obvious. Nevertheless, Taylor's original rules suggested $\lambda_\pi = 1.5$ and $\lambda_y = 0.5$. Thus, Taylor's assumption of $\lambda_\pi > 1$ implied that increases in inflation would lead to higher real interest rate in the economy.[10] The estimated coefficients of the Taylor rule could portray the Fed's monetary policy conduct during the Volcker and Greenspan period quite closely. In consensus models underlying the reactions of monetary authorities under constrained discretion, the relationships of short-term (policy) interest rates and output *via* the real interest rate have come to be regarded as almost axiomatic.

In the subsequent literature, the Taylor rule underwent some modifications in an attempt to make it more realistic and appropriate for monetary policy purposes (see Carare and Tchaidze, 2005). First, forward looking behaviour of agents was incorporated in the reaction function in order to overcome the

---

[9] According to Woodford (2001), Taylor rule can be derived as a solution to the optimization problem with central banks minimizing a loss function in terms of inflation and output gap.

[10] As monetary policy would react more than proportionately to inflation gap, the nominal interest rate would be >1; with given π, real interest would rise.

short-sightedness of the policy makers. Central banks take into account a larger set of information including inflation and output expectations while setting interest rates (Clarida, Gali and Gertler, 2000). Second, McCallum (1999) observed that lagged rather than contemporaneous values of explanatory variables in the rule ensures more realistic timing. The reason is that while setting interest rate, the actual values of inflation and output gap are available only with a lag to the monetary authorities. Third, introduction of interest rate smoothing behaviour due to a variety of reasons such as model uncertainty, loss of credibility due to sudden significant reversals in policy, and need of consensus for a change in policy.[11] Fourth, as suggested by Taylor (1999) and Oprhanides and Williams (2002), replacement of output gap with unemployment gap improves the fit of the data. Fifth, policy maker's reaction to variables such as exchange rate and stock prices should also enter the reaction function (see also Kozicki, 1999).

The present co-existence of low inflation and low growth in large parts of the world economy presents a fresh challenge to the conduct of monetary policy. At one end of the spectrum lies the continuity view which essentially treats the present economic slowdown as an unusual supply shock within the context of the present anti-inflationary monetary stance. At the other end is the view which assigns central banks a much greater pre-emptive role in smoothening output fluctuations, especially as financial imbalances are increasingly able to create disturbances in the real economy without necessarily showing up in overt inflation rate at the initial stages (Borio, English and Filardo, 2003). Notwithstanding the lively academic debate over the policy rules regarding the inflation-growth trade-off, the more standard central banking practice often lies in the 'middle ground' of constrained discretion (Bernanke, 2003). This is built on the parsimonious principle that within its strong commitment to price stability, monetary policy should strive to limit cyclical swings in effective demand.

---

[11] Clarida, Gali and Gertler (2000) argue that despite doubts about the theoretical plausibility of including interest rate smoothing parameter in the Taylor rule, it appears to be appealing intuitively.

Section III

Measurement of Inflation and Output Gap

The measurement of inflation and output gap is the most challenging problem encountered in truly assessing the simple operating rules in many advanced and developing economies such as India. Estimation of Taylor rule or Taylor type rules have raised a number of issues that need to be taken into account while designing Taylor-type rules (Hamalainen, 2004). These include (i) different ways to measure inflation, (ii) timing of information available with the monetary authorities while deciding policy actions – appropriateness of using contemporaneous versus lagged information, (iii) forward looking nature of central banks, and (iv) interest rate smoothing behaviour of central bank.

Among the issues specific to the Indian context, first is choice regarding the appropriate measure of inflation to estimate Taylor rule. Whether one should choose wholesale price index (WPI), goods and services deflator or consumer price index (CPI)? Another issue relating to choice of price measure is whether one should take only the core inflation, i.e., core WPI, core CPI and CPI excluding food and energy prices, as policy should not respond to the volatile component. Alternatively, should the policy rule also consider the volatile component of price such as food and energy which people need to purchase and can constitute a significant part of consumption basket in developing economies.[12] In India, for policy assessment the inflation rate based on the WPI is widely used. However, the divergent trends in inflation as measured by the WPI and CPI in the recent years, have warranted a closer relook at the measurement issues as well as the choice of an appropriate price index for monitoring changes in price levels at the national level that could be used as a reference indicator for the conduct of policies. In the absence of a nationwide

[12] To overcome issues posed by supply shocks, core measures of inflation are often recommended as a target. In developing countries, a measure of core inflation excluding food items – which can account for more than half of the weight in the index – may not be very meaningful (Jalan, 2002), although from the viewpoint of formulation of monetary policy, it is the underlying inflation or core inflation that is important.

single inflation indicator based on consumer prices covering the entire population, the WPI has been used as the headline inflation indicator as it is more representative and provides information on prices with minimum lag.

Second key issue is the measurement of output gap. The output gap can be measured by various methods of estimating the potential output or the permanent component such as simple trend method, Hodrick-Prescott filter, band-pass filter, Kalman filter and the moving average method. A major criticism of the Taylor rule is its dependence on estimates of output gaps. It is argued that potential output (GDP) cannot be observed and attempts to estimate the same can hardly provide reliable estimates.

Third, how the monetary policy stance can be proxied? The standard practice in the developed economies is to specify it in terms of central bank discount rate. In India, the transmission channels of monetary policy have undergone significant changes in the recent decades.[13] Till the 1980s, the key instruments of monetary policy were quantitative such as changes in CRR, directed credit norms and statutory liquidity ratio (SLR). With a move to market determined interest rates during the 1990s, along with a switch from direct to indirect instruments of monetary operations, interest rate emerged as the key transmission channel of monetary policy. Thus using interest rate to measure the overall stance of monetary policy over long horizon has its own limitations. Given the lack of availability of a uniform interest rate variable, for temporal analysis over a long horizon, one has to use a proxy rate for the monetary policy stance such as call money rates or interest rates on government bonds.[14]

Further, the data revisions pose a serious challenge to estimating policy rules with real time policy recommendation differing significantly from those based on the ex-post data. Orphanides (2001) argued that estimated policy

---

[13] Nevertheless it cannot be concluded that monetary policy stance was not reflected in short-term market interest rate. In fact, the quantitative instruments of the policy were expected to ultimately influence the short-term interest rate in the domestic market.

[14] One could also specify monetary policy stance by growth in monetary aggregates but it is not certain how far the monetary aggregates would reveal the monetary policy actions.

reaction function based on the revised data provide ambiguous picture of historical policy and cast a shadow on the behaviour recommended by the information available to the Fed on a real time basis.

The Reserve Bank broadly followed a monetary targeting rule with feedback from the mid-1980s onwards till around 1997-98. Broad money (M_3) served as the intermediate target with the cash reserve ratio (CRR) as the operating instrument. The theoretical underpinnings of monetary targeting were based on a stable relationship between money, output and prices.[15] By the latter half of the 1990s, the growing complexities of monetary management emanating from liberalisation and openness required that the policy formulation be based on a wide range of inputs rather than being predicated on a single monetary aggregate. Accordingly a shift to multiple indicator approach took place in 1998-99. A host of macroeconomic variables, such as interest rates or rates of return in different markets, currency, credit, fiscal situation, trade, capital flows, inflation rate, exchange rate and refinancing are now juxtaposed with output trends for drawing policy inferences. The deregulation of interest rates during the 1990s was central to developing an interest rate channel of monetary transmission.

The stated objectives of the monetary policy in India are maintaining price stability and ensuring the availability of credit to the productive sectors of the economy.[16] Over the period, however, the monetary policy has evolved to have multiple objectives of price stability, output growth and financial stability. Price stability and growth have been the cornerstone of monetary policy conduct in India going back to the 1950s. The theory tells us that choice of these objectives inevitably involves a consideration of welfare, *i.e.*,

---

[15] In the Indian case, money demand was generally found to be stable, providing reasonable predictions of average changes in prices over a medium-term horizon, though not necessarily on a year-to-year basis (Rangarajan and Arif, 1990; Jadhav 1994). The money stock target was believed to be relatively well-understood by the public at large. All these factors provided a rationale for monetary targeting in the Indian context (Rangarajan 1988; 1997).

[16] Given properly designed monetary policy rules, the key socially important objectives of price stability and growth, thus, tend to be mutually reinforcing rather than competing goals.

Table 1: Stylised Facts on Inflation, Output Growth and Interest Rate						
						(Per cent)
Period	WPI inflation	CPI(IW) inflation	Real GDP growth rate	Real Non-Agriculture GDP growth rate	Call money rate	Interest rate on Government bonds
1	2	3	4	5	6	7
1950s	1.7	1.9	3.6	4.5	2.3	3.4
1960s	6.3	6.7	4.0	5.2	4.4	4.6
1970s	9.0	8.0	3.0	4.1	8.3	5.9
1980s	8.0	8.9	5.6	6.1	9.5	9.9
1990s	8.1	8.5	5.7	6.5	11.7	12.3
2000s	5.4	5.7	7.2	8.1	6.4	7.8

WPI: Wholesale price index. CPI (IW): Consumer price index for industrial workers.

deviations of inflation and growth from the chosen combination cause losses of macroeconomic welfare.[17] The conduct of monetary policy should be directed towards minimising these welfare losses. The critical policy choice is the relative importance or weights to be assigned to deviations of output and inflation from the targets. This involves knowledge of the structural characteristics of the economy. In terms of the model, this can be expressed through a simple three equation system specifying aggregate demand, aggregate supply and a policy rule setting out the response of the monetary policy to fluctuations in demand and supply.

The various indicators of inflation provide different rates of inflation in India, nevertheless, the direction of change broadly remains the same over the period 1950-51 to 2009-10 (Table 1). Alternative measures of GDP growth rate i.e., total GDP growth rate and GDP growth rate excluding agriculture, which is periodically affected by the supply shocks, also witness the similar movement. In the recent decades, with a decline in the share of agriculture in GDP and its weakening inter-sectoral linkages with the remaining sectors, the correlation between the total GDP growth and the growth rate of non-

[17] There is considerable agreement among academics and central bankers that the appropriate loss function involves stabilising inflation around an inflation target as well as stabilising the real economy represented by the output gap (Svensson, 1999b).

Table 2: Alternative Measures of Core Inflation and Output Growth

(Per cent)

Period	WPI core inflation		CPI core inflation@	Potential output growth rate	
	HP filter@	BP filter@@		HP filter@	BP filter@@
1	2	3	4	5	6
1950s	4.0	1.6	1.9	4.9	3.7
1960s	6.0	6.2	6.7	4.7	3.6
1970s	7.9	8.3	8.0	4.7	3.4
1980s	8.0	7.6	8.9	5.6	4.8
1990s	7.0	7.7	8.5	6.7	5.6
2000s	6.0	4.9	5.7	7.4	6.8

@ Based on the sample period 1950-2009, using Hodrick-Prescott filter.

@@ Based on the sample period 1950-2009, using Baxter-King Band Pass filter.

agricultural GDP has become very high. It suggests that the use of these alternative measures of output growth would not have significant impact on the characterisation of monetary policy reaction function. Similar is the case with the indicators of monetary policy stance, i.e., average call money rates, weighted average interest rate on government bonds or growth in monetary aggregates.

Various measures of potential output and core inflation have been used in the empirical literature to ascertain the sensitiveness of the monetary policy characterisation in the framework of a Taylor rule. In the Indian context, we observe that the alternative measures of potential output, based on various filtering methods, although provide marginal differences in the scales, the direction of change over the decades remains the same.[18] This implies that there may not be much impact on the empirical estimates of Taylor rule by using different output measures. Furthermore, within the core inflation measure, there does not seem to be any significant divergence among alternative measures of core inflation (Table 2). The use of such alternative measures of interest

[18] In Taylor (1999), the Hodrick-Prescott filter is used instead to generate residuals from trend.

rate, inflation and potential output may, thus, have only marginal impact on the empirical characterisation of monetary policy in India (see also Annex 3).

Section IV

Empirical Estimates of Inflation and Growth Coefficients

In the empirical studies, alternate reaction function have been estimated using ordinary least squares or instrumental variables in case of backward looking functions and generalised method of moments in case of forward looking rules. Most empirical literature on Taylor rule has used a variant with introduction of lagged interest rate in the original Taylor equation.[19] The modified Taylor Rule thus assumes the following form:

$$i_t = \gamma 0 + \gamma_1 r_{t-1} + (1-\gamma_1)(\theta_\pi \pi_{t+i} + \theta_y y_t) + \varepsilon_t \tag{4}$$

where, i = short-term nominal interest rate, r = long-term real interest rate, π = inflation gap and y = output gap. In the original Taylor equation, if the smoothing term γ_1 is close to unity, the Taylor rule would yield large interest rate changes because it effectively adds to the previous interest rate the response to current economic conditions. However, in the above equation, a large smoothing term would imply small changes in interest rates as they will remain close to the level of the previous period. Rational expectations imply that long term interest rates would move in consonance with the expected short term interest rates. Thus, if aggregate demand is assumed to be determined by the long term interest rate, the monetary policy can stabilise output fluctuations without recourse to large scale policy rate changes (Taylor, 1999, 2000; Levin et al., 1999; Woodford, 2001). If aggregate demand responds to short term movement in interest rates, then inefficiency caused by interest rate smoothing could be minimised.

Expectations have played an important role in modifying the empirical application of Taylor rule. Thus, based on the timing of formulation of the monetary policy, Carlstrom and Fuerst (2000, 2001) proposed forward looking

[19] For a detailed discussion on this, reference can be made to Woodford (2003).

and backward looking policy rules. The forward looking rules are based on the premise that monetary authorities can make decisions based on the expected economic conditions. The argument for forward looking rules emanates from the presence of transmission lags in the implementation of monetary policy and its effects on inflation and output (Batini and Haldane, 1999). Batini and Haldane (1999) illustrate that in cases where wage bargaining is backward looking, forward looking rules could counter balance the backward looking behaviour of economic agents. Alternatively, where wages are fully flexible, forward looking rules are not warranted. Forward looking rules, on the other hand, are theoretically justified on the ground that such rules tend to avoid indeterminacy in monetary policy. Rudebusch and Svensson (1999), using a backward looking Taylor rule, proved that such rules outperform the contemporaneous rules. Thus, the forward and backward looking policy rules differ in terms of timing of the monetary policy instrument to react to the explanatory variables. These variants of the Taylor rule can be nested in the following specification:

$$i_t = \gamma 0 + \gamma_1 r_{t-1} + (1-\gamma_1)\ E_{t-j}\ (\theta\pi_{t+k} + \theta_y y_{t+m}) + \varepsilon_t \tag{5}$$

where j denotes a possible information lag for the central bank. Thus, under the forward looking rule, when the central bank reacts to expectations of future inflation/output gap, sets k| m≥0. Under the backward looking rule, it sets k| m≤0.

Another variant of Taylor rule given by Walsh (2003) assumes that under a discretionary policy, the central bank can maximise social welfare by reacting to variations in output gap. The rule, thus, assumes the following form:

$$i_t = \gamma 0 + \gamma_1 r_{t-1} + (1-\gamma_1)\ (\theta_\pi \pi_{t+i} + \theta_y\ \Delta y_t) + \varepsilon_t \tag{6}$$

Furthermore, it is argued that the central bank behaviour could be better characterised by a rule which incorporates an error correction form. Judd and Rudebusch (1998) formulated the following empirical form:

$$\Delta i_t = \gamma 0 + \gamma_1 r_{t-1} + \gamma_2 \Delta r_{t-1} + \theta_\pi \pi_{t-1} + \theta_y\ \Delta y_{t-1}) + \varepsilon_t \tag{7}$$

Giannoni and Woodford (2003) advocate a rule that also related changes in interest rates to inflation and changes in output gap. We estimate first, simple Taylor rule with contemporaneous interaction between interest rate, inflation and output gap. Subsequently, we capture expectations and interest rate smoothing behaviour of monetary authorities.

There are few empirical works characterising monetary policy in a Taylor rule framework in India. RBI (2002) provided estimates of the Taylor rule in simple OLS framework indicating monetary policy reacting more to output gap than to inflation. These estimates based on the sample period 1970-2000, however, do not take into account the structural break in the underlying relationship. Virmani (2004) found that RBI has been conducting its monetary policy as if it were targeting nominal income. The findings are, however, based on a short sample for the 1990s. Singh and Kalirajan (2006) found that the monetary policy reacts when inflation or output gap rises, however, the effectiveness seems to be marginal. Ranjan, Jain and Dhal (2007) observed the monetary policy reacting more strongly to output gap than inflation gap in the recent period. However, given the sample period limitation, difficulties in gauging the monetary policy stance through a weighted average index and a high sensitivity of results to lag specification, it would be difficult to derive a credible conclusion. Banerjee and Bhattacharya (2008) found that the evidence seems to be more consistent with changes in policy interest rates being determined by the output gap rather than current inflation. Their estimates, however, do not seem to be reliable due to a short sample period and methodological weaknesses. Inoue and Hamori (2009) find that while the output gap coefficient was significant the same was not true for the inflation coefficient. They use a very short sample and output gap is estimated using industrial production data, which explains only about 20 percent of India's GDP.

The advantage of alternative measures of Taylor rule is that it provides us reasonable idea about the robustness of the inflation and growth parameters. We estimate various models using annual data as the estimates of output for the period prior to 1997-98 are available only at an annual frequency. We first proceed to estimate the Taylor rule for the entire sample period spanning 1950-51 to

2008-09 to understand the historical behaviour of monetary policy in India. The monetary policy stance is defined in terms of short-term money market interest rate (i.e., call money rates) as the monetary policy operates to influence short-term interest rates. It is sometimes argued that in the period till the mid-1980s, quantitative measures dominated the RBI's monetary operations, thus, one should use such measure to identify monetary policy stance. However, we argue that the quantitative measures of monetary policy stance such as changes in CRR ultimately influence short-term interest rate. During the period 1950s to 1980s, when the quantitative measures dominated the policy instruments, the coefficient of correlation between the call money rates (representing the central bank's interest rate stance) and the CRR was a high of 0.85, suggesting that call money rates could still be well representative of central bank's monetary policy stance. In fact, a unidirectional causal relationship from CRR to call money rates has been observed (Table 3). Similarly we find a high coefficient of correlation between the call money rates and the money growth at 0.68, buttressing the argument that the impact of all the quantitative measures was subsumed in short-term interest rate, which monetary policy targets, to influence prices and output. Inflation gap is measured in terms of deviation of WPI inflation from the underlying decadal average inflation rates and output gap is measured in terms of deviation of actual real GDP from the potential real GDP measured in terms of Hodrick Prescott filter.[20]

It is evident from Table 4 that although the coefficients of inflation and output gap vary in significance across various types of models, the size of the

Table 3: Causal Relationship between Call Money Rates, Cash Reserve Ratio and Money Growth (Sample 1951-1988)

Null Hypothesis:	F-Statistic	Prob.
1	2	3
CRR does not Granger cause call rate	9.88	0.00
Call rate does not Granger cause CRR	0.84	0.44
Money growth does not Granger cause call rate	4.86	0.02
Call rate does not Granger cause money growth	4.14	0.03

[20] We have also experimented with potential GDP based on Baxter-King Band Pass filter method.

coefficient of output turns out to be larger than that of the inflation gap.[21] Monetary policy seems to have reacted more than proportionately to output gap across the most models, however, the parameters are mostly insignificant. The inflation parameters generally seem to be significant but suggesting less than proportional response of monetary policy to inflation gap. Given the standard errors of the estimated parameters of the model and the Schwartz information criteria, Taylor rule estimated through two-stage least square (TSLS) method with interest rate smoothing and backward-looking Taylor rule based on generalised method of moments (GMM) seem to be the best models describing monetary policy over a long horizon.[22] A backward-looking Taylor rule indicates that the parameter of output gap is much larger than that of inflation gap. The interest rate smoothing parameters in all the models is significant, suggesting that there is instantaneous adjustment of policy rates to the rule.[23] It is argued

Table 4: Estimated Monetary Policy Rules for India: 1951-2009

Models	γ_0	γ_1	θ_π	θ_y	δ_{1dum75}	δ_{2dum88}	$\bar{R}^2$	DW	SIC	J-Stat
1	2	3	4	5	6	7	8	9	10	11
Taylor Rule with Interest Rate Smoothing (OLS)	0.07 (7.24)	0.74 (6.42)	0.35 (1.77)	0.47 (0.86)	0.04 (4.90)	0.01 (2.12)	0.63	2.18	-4.36	
Taylor Rule with Interest Rate Smoothing (TSLS)	0.08 (6.55)	0.75 (6.12)	0.85 (2.13)	1.51 (1.51)			0.60	2.00	-7.25	
Backward Looking Taylor Rule (OLS)	0.08 (7.51)	0.72 (5.65)	0.33 (2.92)	0.96 (1.30)		0.01 (2.03)			-4.36	
Backward Looking Taylor Rule (GMM)	0.07 (8.13)	0.70 (5.80)	0.27 (1.91)	1.04 (1.79)			0.60	2.01	-7.25	0.02
Forward Looking Taylor Rule (OLS)	0.07 (6.93)	0.75 (6.63)	0.19 (1.27)	0.34 (0.60)	0.06 (11.70)		0.62	2.13	-4.37	
Forward Looking Taylor Rule (GMM)	0.06 (7.49)	0.73 (5.81)	0.73 (1.45)	1.83 (0.99)			0.43	2.09	-6.87	0.05

21 We estimate various models with hetertoskedasticity consistent coefficient covariance. The robustness tests such as LM test for residual serial correlation and normality tests are also applied to various estimated models.

22 We also estimated Taylor rules in other variants of econometric models. As the estimates were not robust, we have not reported the results for such models.

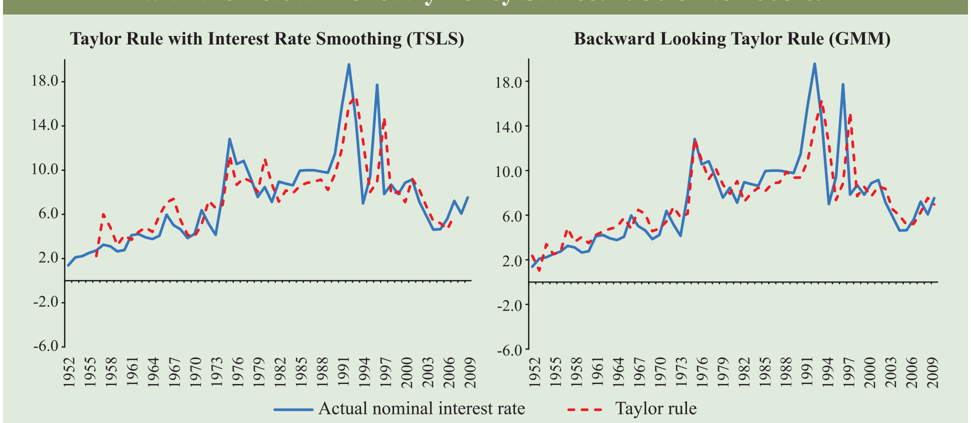
23 The interest rate smoothing behaviour could be due to a number of reasons such as: (i) central bank may avoid frequent revisions as these could be construed as mistakes and compromise the confidence in the central bank (Williams, 1999); (ii) unavailability of accurate economic information with the central banks and the uncertainties they face regarding the transmission of policy actions and the state of the economy may drive them to adjust slowly to their targets (Sack and Wieland, 1999).

that if the lagged interest rate term yields large and significant coefficient, the interest rate smoothing is deliberate by the policy actions (Sack and Wieland, 1999). A general conclusion that emerges from alternative estimates is that for the entire sample, monetary policy seems to have reacted more strongly to output gap than to the inflation deviations from long run path.

Chart 1 illustrates the Taylor rule based short-term interest rates and the actual short-term interest rates for two benchmark models for the entire sample period 1950-51 to 2008-09 with $\bar{R}^2$ of around 0.60.[24] While the actual interest rate somewhat deviated from the policy rule recommended interest rate for the period up to the early 1980s, which was marked by two major oil price shocks, the latter period exhibited close movement between the rule recommended and the actual rates. The broader message is that monetary policy seems to have balanced the inflation and output concerns over a longer horizon.

The above mentioned estimates, however, need to be seen in the context of the structural shifts in the monetary policy framework over the decades with clear emphasis on inflation with announcements of targeted inflation trajectory and perceptible shift towards interest rate as a key instrument of

Chart 1: A Comparison of the Model-based Estimates of the Taylor-type Rule with the Actual Monetary Policy Stance: 1950-51 to 2008-09



24 The plots for the remaining models are presented in Annex 1.

monetary policy. In macroeconomic models with rational expectations, parameters of the model depend upon the monetary policy regime in place (Judd and Rudebusch, 1998). In order to account for such underlying structural shifts in the relationships, we conduct various tests for structural break. The results from the switching regression model suggest a structural break in the short-term interest rate (i.e., weighted average call rate) in the late 1980s and AP breakpoint test also suggest a break in the residuals in 1988-89. Accordingly, we estimate the Taylor rule for two sub-samples i.e., 1950-51 to 1987-88 and 1988-89 to 2008-09.

The estimated models for the first sample period (i.e., 1950-51 to 1987-88) suggest that mostly the parameters of inflation and output gap are insignificant across models (Table 5). Again the interest rate smoothing parameters is significant and sizeable, suggesting that short-term interest rate strongly adjust to the rate recommended by the policy rule. The rule with interest rate smoothing estimated with the help of two-stage least squares method yields a statistically significant parameter for inflation gap, which suggests relatively low response of monetary policy to deviations in inflation from its long run path. The plot of the actual short-term interest rate and those recommended by the Taylor rule are illustrated in Annex 2. The results for this period need to be interpreted with caution as the monetary policy framework was based on the underlying money, output and price orthodoxy and interest rate seemingly did not adequately capture the monetary policy stance. In order to address this structural feature of the period, we estimated Taylor rule with introduction of some quantitative variables such as money growth gap and changes in CRR, which was a key instrument of monetary policy signalling, however, we do not find distinct changes in the robustness of results even with these additional variables.[25] [26]

[25] In the estimated Taylor rule model with M3 growth specifying the monetary policy stance for the period, we find that though the smoothing parameter is significant and large (0.65), parameters relating to inflation and output gap still remain insignificant. When the monetary policy stance is estimated by CRR, the coefficients of inflation and output gap still turn out to be insignificant.

[26] A backward-looking Taylor rule estimated using GMM method with M3 growth specifying the monetary policy stance reveals that the coefficients relating to interest rate smoothing (0.65) and output gap (0.85) were significant. This implies that monetary policy reacted significantly to output shocks in the earlier period.

Table 5: Estimated Monetary Policy Rules for India: 1951-1988

Models	γ_0	γ_1	θ_π	θ_y	$\gamma_{2\Delta rt-1}$	$\theta_{\Delta y}$	δ_{Dum75}	$\bar{R}^2$	DW	SIC	J-Stat
1	2	3	4	5	6	7	8	9	10	11	12
Taylor Rule with Interest Rate Smoothing (OLS)	0.08 (3.92)	0.88 (20.00)	0.74 (1.21)	-0.44 (-0.56)				0.81	1.57	-6.54	
Taylor Rule with Interest Rate Smoothing (OLS with lag output)	0.07 (5.15)	0.85 (15.40)	0.33 (1.81)	0.69 (1.01)			0.04 (6.54)	0.88	2.23	-5.92	
Taylor Rule with Interest Rate Smoothing (TSLS)	0.08 (3.19)	0.90 (15.36)	0.75 (0.59)	-0.59 (-0.31)				0.82	2.03	-8.44	
Taylor Rule with Interest Rate Smoothing (GMM)	0.06 (5.82)	0.84 (10.69)	-0.51 (-0.86)	0.53 (0.36)			0.07 (8.70)	0.78	2.08	-8.46	0.09
Forward Looking Taylor Rule (OLS)	0.07 (5.55)	0.85 (15.80)	0.19 (0.95)	-0.15 (-0.23)			0.05 (9.49)	0.87	2.36	-6.05	
Forward Looking Taylor Rule (GMM)	0.07 (4.99)	0.88 (12.11)	-0.76 (-1.28)	0.10 (0.05)				0.74	1.82	-8.01	0.08
Backward Looking Taylor Rule (OLS)	0.08 (4.36)	0.88 (15.67)	0.33 (1.34)	0.72 (0.86)				0.80	2.05	-5.62	
Backward Looking Taylor Rule (GMM)	0.06 (5.74)	0.88 (19.42)	-0.06 (-0.46)	1.18 (1.38)				0.76	1.65	-8.10	0.07
Giannoni and Woodford (2003) (GMM)	0.01 (2.25)	-0.14 (-1.71)	-0.04 (-0.31)		-0.32 (-0.45)	-0.03 (-0.32)	0.09 (1.62)	0.26	2.38	-6.42	0.02
Walsh (2005) Difference Rule (GMM)	0.00 (0.89)		0.10 (0.97)			0.23 (2.24)		0.32	1.64	-6.87	0.13
Judd and Rudebusch (1998) (OLS)	0.01 (4.03)	-0.17 -(3.05)	0.01 (0.42)	0.13 (2.25)	-0.19 (-2.48)		0.08 (10.84)	0.60	2.00	-6.11	

The second sample period (i.e., 1988-89 to 2008-09) reflects important changes in the operating framework of monetary policy and closer approximation of monetary policy through short term interest rates. The alternative model estimates yield statistically robust results for parameters relating to inflation, output and interest rate smoothing as presented in Table 6. The alternative models also passed the robustness tests such as LM test for serial correlation among the residuals and the normality tests. The most estimated models with reasonable explanatory power and significant parameters lead to the robust conclusion that monetary policy reacts more than proportionately to deviations in inflation and less than proportionately to output gap. The parameters of monetary policy reaction to inflation gap range

Table 6: Estimated Monetary Policy Rules for India: 1989-2009

Models	γ_0	γ_1	θ_π	θ_y	$\gamma_{2\Delta rt-1}$	θ_{y1}	ρ_{exr}	$\bar{R}^2$	DW	SIC	J-Stat
1	2	3	4	5	6	7	8	9	10	11	12
Taylor Rule with Interest Rate Smoothing (OLS)	0.09 (10.06)	0.38 (2.56)	1.28 (2.96)	0.80 (1.79)				0.49	2.31	-4.01	
Taylor Rule with Interest Rate Smoothing (TSLS)	0.09 (8.40)	0.32 (1.34)	1.08 (1.80)	1.01 (2.57)				0.39	2.13	-6.46	
Taylor Rule with Interest Rate Smoothing (GMM)	0.09 (14.24)	0.36 (2.49)	1.71 (5.06)	0.74 (2.21)				0.44	2.14	-6.55	0.10
Taylor Rule with Interest Rate Smoothing (GMM) and Exchange Rate	0.24 (5.37)	0.28 (4.46)	1.25 (5.28)	0.40 (2.22)			-0.03 (-3.66)	0.48	2.13	-6.55	0.16
Forward Looking Taylor Rule (OLS)	0.08 (9.13)	0.47 (2.29)	0.87 (1.17)	0.42 (0.69)				0.52	1.83	-3.73	
Forward Looking Taylor Rule (GMM)	0.07 (4.55)	0.80 (4.90)	-1.08 (-0.52)	3.66 (0.72)				0.04	2.24	-6.03	0.09
Backward Looking Taylor Rule (OLS)	0.09 (15.44)	0.06 (0.19)	1.06 (5.05)	1.10 (2.58)				0.55	1.67	-3.94	
Backward Looking Taylor Rule (OLS) with Exchange Rate	0.23 (5.1)	-0.07 (-0.25)	0.85 (3.50)	0.89 (2.99)			-0.04 (-3.74)	0.65	1.96	-4.11	
Backward Looking Taylor Rule (GMM)	0.09 (10.91)	0.60 (10.20)	1.06 (3.73)	1.04 (3.19)				0.34	2.23	-6.09	0.08
Backward Looking Taylor Rule (GMM) with Exchange Rate	0.16 (4.88)	-0.26 (-2.38)	0.80 (6.69)	0.43 (2.93)			-0.03 (-2.24)	0.48	1.32	-6.55	0.13
Giannoni and Woodford (2003) (GMM)	0.11 (3.65)	-1.22 (-4.26)	1.83 (2.14)		0.88 (1.97)	-0.40 (-0.35)		-0.63	2.02	-5.54	0.03
Walsh (2005) Difference Rule (GMM)	0.00 (1.85)		0.57 (2.08)			0.46 (2.36)		0.03	2.21	-6.23	0.09
Judd and Rudebusch (1998) (OLS)	0.09 (3.40)	-0.98 (-3.56)	1.05 (2.61)	1.04 (2.67)	0.09 (0.53)			0.46	1.69	-3.81	

from 1.05 to 1.78. The statistically significant parameters of output gap range from 0.71 to 1.10 in the alternative models. The parameters relating to output gap in the Indian context are much larger than those in the advanced economies given the significant welfare implications of a drop in output growth.

The interest rate smoothing parameter yielded by the benchmark models is between 0.28 to 0.60, indicating that the actual rates typically adjust enough to eliminate about 30-60 per cent of the difference between the actual lagged and the rule recommended short-term interest rates each year.[27] The important difference in the interest rate smoothing behaviour of the central bank is the shift from large smoothing in the first earlier period to relatively gradual smoothing in the latter period. These results are consistent with the cautious and measured actions of the central banks due to a number of reasons such as uncertainties surrounding the economic environment and the transmission of policy rates, the scepticism about the impact of interest rate changes, difficulties in disentangling an economic shock from a measurement error and concern about the stability of financial market arising from large interest rate changes. Furthermore, smoothing may also reflect reaction of central bank to inflation and output gap observed over several periods than just the preceding period (Kozicki, 1999). Based on the information criteria, the Taylor rule with interest rate smoothing, estimated using TSLS and GMM methods, seem to be the benchmark models. Both these models indicate that monetary policy reacts relatively strongly and more than proportionately to inflation than the output gap.

It is often argued that in developing economies, central banks implicitly or explicitly lean against the exchange rate movements in order to keep the exchange rate competitive or to contain excessive volatility which hampers the transmission of monetary policy by destabilising domestic financial markets. Exchange rate in the Taylor rule emerges significant in case of contemporaneous GMM estimates and backward looking Taylor rules.[28] The estimated parameter of exchange rate suggests that monetary policy tightens in response to exchange rate depreciation and vice versa, though the adjustment is not sizeable.

The Taylor-type rule characterisation of monetary policy in India for the period 1988-89 to 2008-09 is summarised in Chart 2. Taylor rule with interest rate smoothing, estimated through TSLS and GMM methods seem to provide relatively better characterisation of monetary policy for the recent years. The

---

27 Rudebusch (1995) also presents the view that central banks often adjust interest rates in a gradual fashion by taking small and distinct steps towards a desired setting.

28 We drop exchange rate from other models as it does not result in an improvement in the fit of the models estimated.

Chart 2: A Comparison of the Model-based Estimates of the Taylor-type Rule with the Actual Monetary Policy Stance: 1988-89 to 2008-09

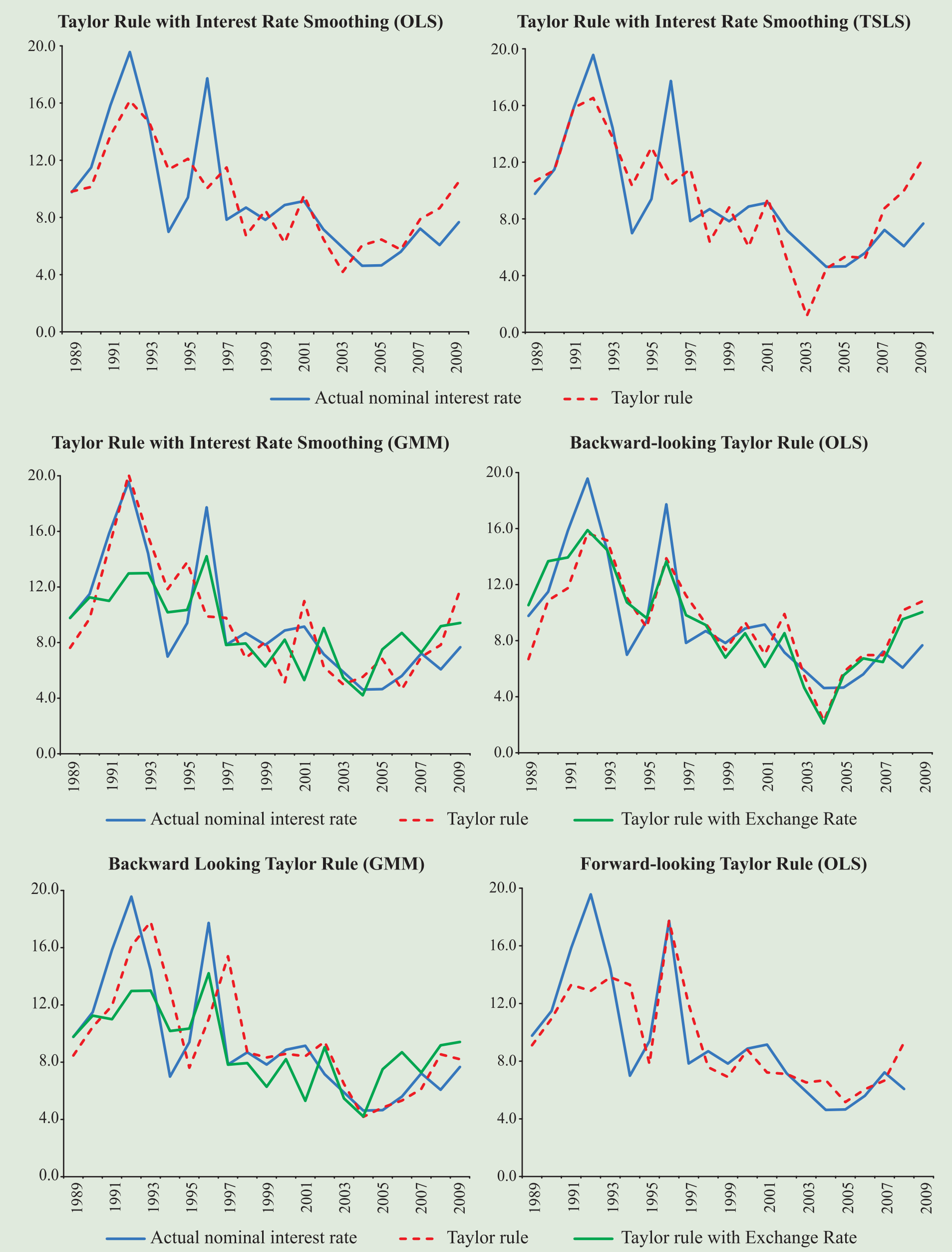
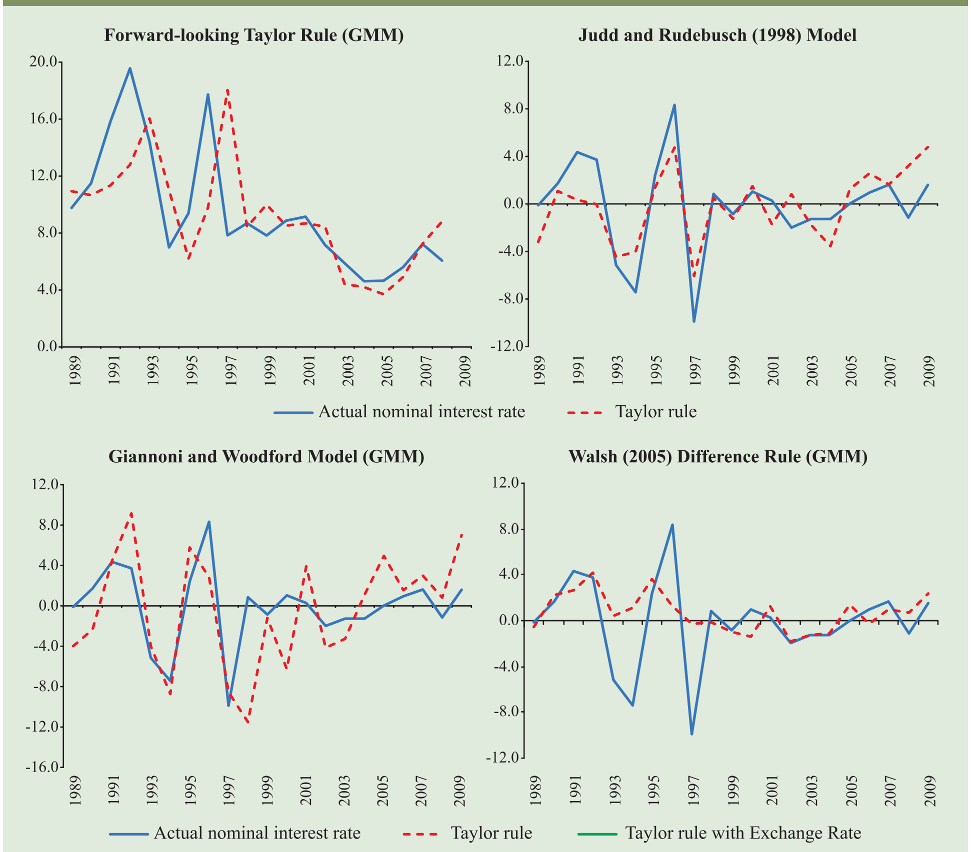


Chart 2: A Comparison of the Model-based Estimates of the Taylor-type Rule with the Actual Monetary Policy Stance: 1988-89 to 2008-09



actual interest rates deviated significantly from the path recommended by the rule in the mid-1990s due to well known credit crunch. Forward looking rules (both based on OLS and GMM estimates) are, however, able to adequately capture the interest rate shock of the mid-1990s. Another important conclusion that emerges from this diagrammatic representation of Taylor rule is that after 2007, the actual short-term interest rates have remained significantly below those recommended by the policy rules, indicating a relatively easy monetary policy stance compared to those recommended by the rules.

Section V

Dynamic Model-based Characterisation of Monetary Policy Rules in India

The Model

We seek to characterise monetary policy stance in India in the framework of Taylor-type rule in a dynamic structural VAR model with output gap, inflation gap and policy interest rate. The standard structural system can be considered of the following linear and stochastic dynamic form:

$$A_0 y_t = B(L)y_{t-i} + \varepsilon_t \text{ with } i = 1, \ldots\ldots\ldots n \tag{8}$$

where y_t is a $k \times 1$ column vector of endogenous variables, y_{t-1} is a vector of the lagged values of y and A_0 is $k \times k$ invertible matrix of structural coefficients, which captures contemporaneous relationship among the variables in y. B is $k \times k$ matrix modelling dynamic interaction among the k variables. ε_t contains $k \times k$ structural coefficients signifying the effect of k structural shocks, whose variance-covariance matrix is a $k \times 1$ column vector of disturbance terms. As all the elements of ε_t off the main diagonal of the covariance matrix are zero, this implies that the structural shocks are uncorrelated (orthogonal).[29]

In the model $y_t = (y_{gap}, \pi_{gap}, r)$, where y_{gap} = real output gap, π_{gap} = inflation gap, r = short-term interest rate signifying the policy stance. Corresponding to (8), the reduced form representation can be obtained by premultiplying (8) with the inverse of $A_{0.}$

$$A^{-1}_0 A_0 y_t = A^{-1}_0 \mathrm{B}(L)y_{t-i} + A^{-1}_0 \varepsilon_t \tag{9}$$

Thus,

$$y_t = A(L)y_{t-i} + e_t \qquad\qquad e_t \sim N(0,I) \tag{10}$$

with $A^{-1}_0 B(L) = A(L)$ and $A^{-1}_0 \varepsilon_t = e_t$.

[29] The structural disturbances have a Gaussian distribution with $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon' t) = I$.

Thus, in the reduced form all the variables appearing on the right hand side are predetermined at time t, implying that no variable has a contemporaneous effect on other variables in the system. The errors in the reduced form are composites of structural shocks such that $e_t = A^{-1}_0 \varepsilon_t$. Thus, the structural shocks can be recovered from the residuals with $\varepsilon_t = A_0 e_t$.[30] In order to derive the structural parameters from estimates of the reduced form parameters, restrictions on the system are applied based on economic theory.[31] Thus, in order to identify the n^2 unknown from the known $(n^2 + n)/2$ independent elements of Σ, it is necessary to impose $(n^2 - n)/2$ restrictions on the model (i.e., three restrictions).

$$\begin{bmatrix} e_{ygap} \\ e_{\pi gap} \\ e_r \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ \alpha 21 & 1 & 0 \\ \alpha 31 & \alpha 32 & 1 \end{bmatrix} = \begin{bmatrix} \varepsilon_{ygap} \\ \varepsilon_{\pi gap} \\ \varepsilon_r \end{bmatrix}$$

In the above matrix, first equation indicates that the real activity is not contemporaneously affected inflation gap and interest rate, given the exogeneity of output growth. The inflation gap is, however, contemporaneously impacted by the output gap. It is believed that aggregate demand shocks would have instantaneous impact on prices through their effect on commodity prices, which have flexible prices due to their active tradability. The interest rate equation has the underlying representation of the reaction function of monetary policy. It responds contemporaneously to real output gap, representing the aggregate demand pressures and also to inflation gap, representing supply shocks. Thus, it captures the typical operation of Taylor Rule.

30 In other words, a structural shock ε_{it} can cause shocks in all error terms e_{it} thus generating contemporaneous movement in all endogenous variables.

31 Following the common approach, the structural shocks are identified from their reduced form counterparts by imposing restrictions on the contemporaneous matrix A_0 with 0 denoting no contemporaneous relation and α_{ij} denoting the variables which contemporaneously affect the other variables. ε_j's are the uncorrelated structural shocks and e_j's the observed reduced form errors. Given that the diagonal elements of B are all unity, it contains (n^2-n) known values. There are also the unknown values for var(ε_{it}) for a total of n^2 unknown values in the structural model.

Empirical Results

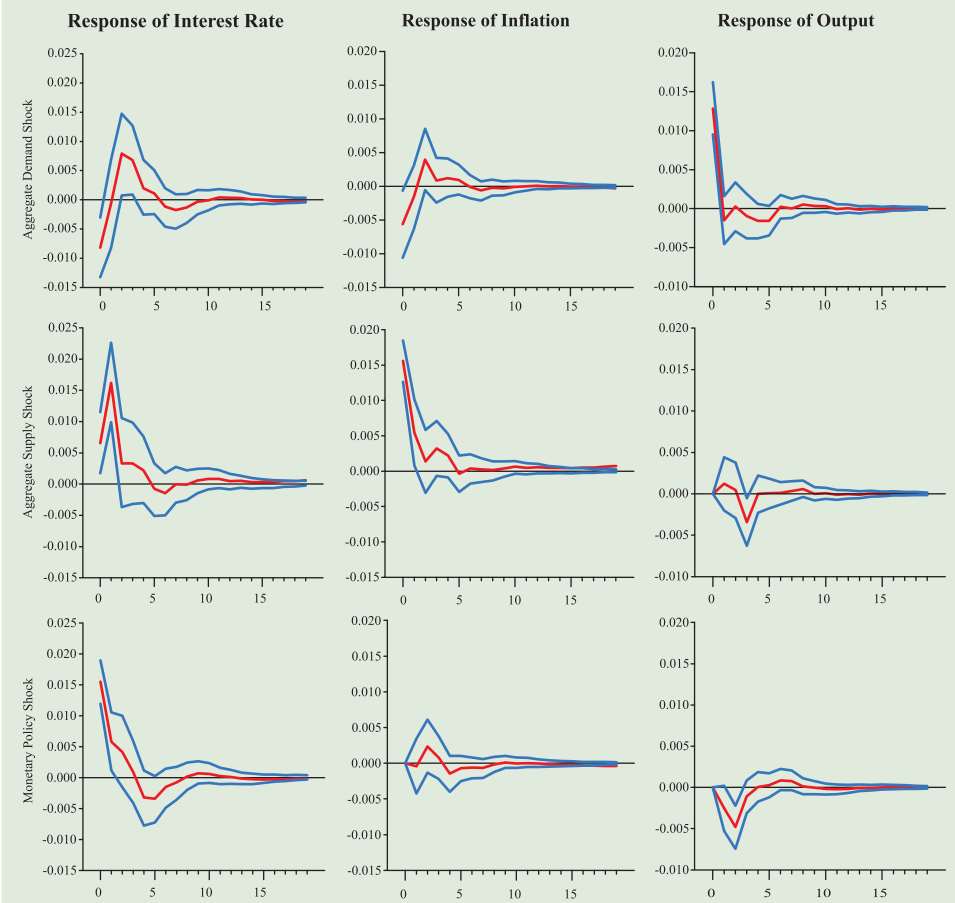
In the absence of an interest rate truly representing the monetary policy stance prior to the 1990s, we use a weighted average of call money market rates as a measure of the stance of monetary policy. We use commonly applied model selection criteria regarding the selection of lag length. As the information criteria suggest a lag length of two years, we allow for two lags. In order to examine the robustness of the model, we carry out various diagnostic tests.[32]

With a view to explain as to how the monetary policy reacts to various shocks, we present the impulse responses to various exogenous (orthogonal) shocks in Chart 3. In response to the aggregate demand shock emanating from strong real activity in the economy, the short-term interest rate (characterising monetary policy) rise strongly up to two years after the initial shock and thereafter level-off by the fourth year. The reaction of monetary policy to supply shocks (emanating from deviation of prices from their medium to long run threshold level) is relatively strong than reaction to output gap and persists for about 3 years after the initial supply shock. In response to a monetary policy shock, interest rate rise sharply in the initial two period and thereafter level-off. The impulse responses thus, tend to suggest that monetary policy is more responsive to inflation deviations than to the output gap.

The conclusions emerging from impulse responses to various exogenous shocks provide us fair idea that the results have theoretical consistency. We then proceed to examine the relative importance of inflation and output gap in explaining variation in short-term interest rates. In other words, we attempt to quantify the contribution of various types of shocks in explaining the variation in policy rates. It is interesting to note that deviation in inflation from its long run path explain the largest proportion of short-term interest rate changes from the second period (Table 7). This reinforces the findings of the alternative

[32] The LM test statistics for the residual serial correlation suggested that the residuals are free from serial autocorrelation up to two lags. This implies that the estimated parameters are robust. The VAR residual normality test also suggested that the null hypothesis of the multivariate normal residuals is not rejected for the test of skewness at 5 per cent level.

Chart 3: Impulse Responses to Various Shocks (Sample: 1988-89 to 2008-09)



models of the monetary policy rule and also those of the impulse response functions that monetary policy in the recent years has emerged strongly

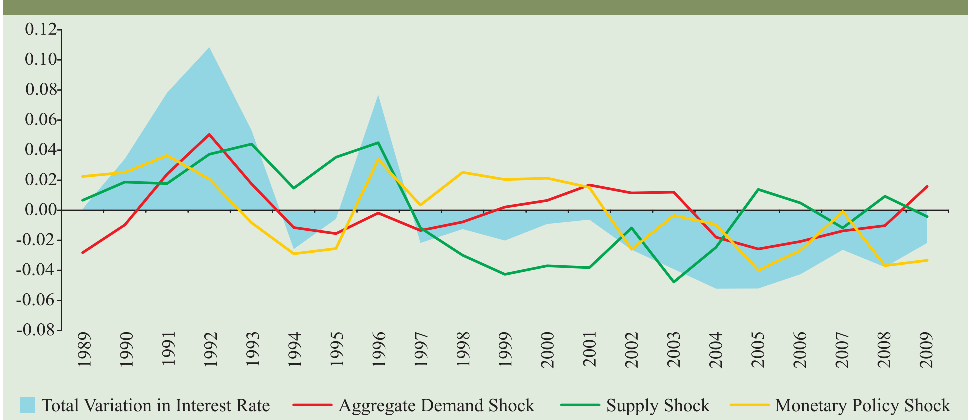
Table 7: Decomposition of Variance of Short-term Interest Rate

Period	Output Gap	Inflation Gap	Monetary Policy	Period	Output Gap	Inflation Gap	Monetary Policy
1	2	3	4	1	2	3	4
1	15.1	12.9	72.0	6	17.4	43.3	39.3
2	8.1	46.9	45.0	7	17.3	43.0	39.7
3	12.8	44.7	42.5	8	17.4	42.7	39.8
4	17.0	43.8	39.2	9	17.5	42.7	39.8
5	17.3	44.2	38.5	10	17.6	42.6	39.8

responsive to inflation shocks. The role of output gap in explaining variation in short-term interest rate is relatively low. The monetary policy shocks itself explains larger variation in short-term interest rate in the short run (i.e., one year), thereafter it declines sharply but with some degree of persistence over the medium term. This could be explained in terms of interest rate smoothing behavior of the monetary policy

We further proceed to explain the major episodes of short-term interest rate variations for the period 1988-89 to 2008-09 by obtaining the historical decomposition of interest rate shocks emanating from the structural VAR model, as presented in Chart 4. The interest rate shock of the early 1990s was led by both demand as well as supply shocks in the economy, when the economy came under the severe external shock from the Gulf crisis. The second major fluctuation in interest rate in the middle of 1990s was led by monetary policy shock in conjunction with the supply shocks. This period was characterised by the credit crunch in the Indian economy. The moderation in interest rates in the 2000s is largely explained by initial large supply shocks which since the middle of the decade were dominated by the monetary policy shocks and to some extent the demand shocks.

Chart 4: Historical Decomposition of Interest Rate Fluctuations



Section VI

Conclusion

The above analysis seeks to characterise the monetary policy stance spanning a long period covering 1950-51 to 2008-09 in order to understand the shifts in the relative weights the monetary policy might have accorded to inflation and output fluctuations – the two key objectives of monetary policy in India, broadly since the 1950s. Although, it may be argued that the earlier regime of conduct of monetary policy in India was essentially a monetary targeting framework, we argue that the impact of quantitative measures was finally reflected in the short-term market interest rates. Therefore, we proceed to characterise monetary policy stance in terms of short-term money market rates and also find that conditioning the monetary policy reaction function with quantitative variables does not significantly change the results in terms of growth and inflation response.

The estimated monetary policy rules with alternative measures of inflation and output gap do not alter the nature of relationship. Furthermore, in order to ensure the robustness of the results and their reliability for deriving firm conclusions, we estimate a range of models suggested in the empirical work. We find that for a historical sample covering 1950-51 to 2008-09, there was perceptible bias in the conduct of monetary policy in terms of stronger reaction to output gap than to deviations in inflation. Monetary policy seems to have broadly reacted more than proportionately to output gap, however, the parameters are mostly insignificant. The inflation parameters generally seem to be significant but suggesting less than proportional response of monetary policy to inflation gap. Since the results are not statistically adequately robust across the models, we test for structural break to account for shifts in the underlying relationships. As the various tests suggest structural break in 1988-89, we estimate models for two sub-samples i.e., 1950-51 to 1987-88 and 1988-89 to 2008-09.

The results for the first period (i.e., 1950-51 to 1987-88) suggest that monetary policy was more responsive to output fluctuations than to the inflation deviations. The results, however, do not seem to be robust in terms of standard errors of the estimated parameters. Even though, we attempt to estimate the monetary policy reaction function by controlling for the impact of quantitative aggregates, the results do not undergo any significant change. For the more recent period (i.e., 1988-89 to 2008-09), however, the results suggest that the monetary policy reacts relatively strongly to inflation deviations from their long run trajectory than to the output gap. The parameters of monetary policy reaction to inflation gap in the alternative models range from 1.05 to 1.78 and those of output gap from 0.71 to 1.10. Furthermore, estimated coefficients for inflation gap have increased significantly between the two periods, suggesting a shift in the emphasis of monetary policy. Taylor rule with interest rate smoothing (estimated through TSLS and GMM methods) seem to provide relatively better characterisation of monetary policy for the recent years. The estimated coefficients of inflation gap in the Taylor rule equation are relatively large as compared to the coefficients of the output gap, suggesting more than proportional reaction of monetary policy to inflation deviations. This also underlines a rising concern of monetary policy to inflation in the last two decades. Exchange rate also impacts monetary policy decisions about interest rate setting in the latter period with shift to market determined exchange rate. The important difference in the interest rate smoothing behaviour of the central bank is the shift from large smoothing in the earlier period to relatively gradual adjustment of short-term interest rates to the policy rule recommended rates in the latter period. This is consistent with the measured actions of central banks given the uncertainties surrounding the economic environment and the transmission of policy rates with increased openness of the domestic financial markets and the economy. The above results are also buttressed by the dynamic estimates from a structural VAR model incorporating the rules. The impulse responses indicate strong reaction of monetary policy to inflation shocks. The variance decomposition analysis also suggests that inflation deviations explain the highest variation in short-term interest rate over short to medium term horizon.

The above findings notwithstanding, rules can only be viewed as thoughtful supplements for the policy. A central bank has to eventually judge the outcome of the policy choices it makes and also take account of and anticipate market expectations, which have become increasingly important for the attainment of desirable outcomes. Taylor (1993, 2000), himself, suggested caution in that simple monetary rule should not be followed mechanically, rather be used as a guideline for policy.

References

Banerjee, Rituparna and Bhattacharya, Saugata (2008), "The RBI's Monetary Policy Reaction Function: Does monetary policy in India follow an inflation targeting rule?" Paper submitted for the Annual Conference on Money and Finance, 2008, IGIDR.

Batini, Nicoletta and Andrew G Haldane (1999), "Forward-Looking Rules for Monetary Policy," In Taylor, J.B. (ed.), Monetary Policy Rules. University of Chicago Press: Chicago.

Bernanke, Ben S (2003), "Friedman's monetary framework: some lessons," Proceedings, Federal Reserve Bank of Dallas, issue October, pages 207-214.

Blanchard, Olivier (2006), "Monetary Policy: Science or Art?" Panel discussion, presented at 'Monetary Policy: A Journey from Theory to Practice', An ECB colloquium held in honor of Otmar Issing, March.

Blinder, Alan S (2006), "Monetary Policy Today: Sixteen Questions and about Twelve Answers," Working Papers 73, Princeton University, Department of Economics, Center for Economic Policy Studies.

Borio, Caludio and P Lowe (2002), "Asset Prices, Financial and Monetary Stability: Exploring the Nexus", BIS Working Paper, No. 114.

Borio, Caludio, W English and A Filardo (2003), "A tale of two perspectives: old or new challenges for monetary policy?", BIS Working Papers no. 127, February.

Borio, Caludio, William R White (2004), "Whither monetary and financial stability? the implications of evolving policy regimes", BIS Working Papers No 147, February.

Carare, Alina and Robert Tchaidze (2005), "The Use and Abuse of Taylor Rules: How Precisely Can We Estimate Them?", IMF Working Paper WP/05/148.

Carlstrom, Charles T and Timothy S Fuerst (2000), "Forward-Looking Versus Backward-Looking Taylor Rules," Federal Reserve Bank of Cleveland, Working Paper No. 0009 (August).

_________ (2001), “Timing and real indeterminacy in monetary models,” Journal of Monetary Economics, Vol. 47, no. 2, pp. 285-98.

Clarida, Richard, Jordi Gali, and Mark Gertler (1999), “The Science of Monetary Policy: A New Keynesian Perspective,” NBER Working Paper 7147, National Bureau of Economic Research.

Clarida, Richard, Jordi Gali, and Mark Gertler (2000), “Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory,” Quarterly Journal of Economics (February), Vol. 115 (1), 147-180.

Friedman, Milton (1959), A program for monetary stability, New York.

Friedman, Benjamin M (2000), “Monetary Policy”, NBER Working Paper no. W8057.

Giannoni, M P and M Woodford (2003), “How forward-looking is optimal monetary policy?” Journal of Money Credit and Banking, Vol. 35, No.6, pp. 1425-69.

Goodfriend, Marvin (2003), “Inflation Targeting in the United States?” paper presented at the National Bureau of Economic Research Conference on Inflation Targeting, Bal Harbour, Florida, January 25.

Hamalainen, Nell (2004), “A Survey of Taylor-Type Monetary Policy Rules”, Working Papers-Department of Finance Canada, 2004-02.

Inoue, Takeshi and Shigeyuki, Hamori (2009), “An Empirical Analysis of the Monetary Policy Reaction Function in India,” IDE Discussion Papers 200, Institute of Developing Economies, Japan External Trade Organization.

Jadhav, Narendra (1994), Monetary Economics for India, Macmillan India Ltd.

Jalan, Bimal (2002), “Research and Policy Developments in Money, Finance and the External Sector”, in M S Ahluwalia, Y V Reddy and S S Tarapore (eds.), Macroeconomics and Monetary Policy: Issues for a Reforming Economy, Oxford University Press, New Delhi.

Judd, John P and Glenn D. Rudebusch (1998), "Taylor's Rule and the Fed: 1970-1997," Federal Reserve Bank of San Francisco Economic Review, no.3, pp.3-16.

Kozicki, Sharon (1999), "How Useful Are Taylor Rules for Monetary Policy?" Economic Review Second Quarter 1999, Federal Reserve Bank of Kansas City.

Levin, Andrew, Volker Wieland, and John C Williams (1999), "A Robustness of Simple Monetary Policy Rules Under Model Uncertainty," in John B. Taylor (ed.), Monetary Policy Rules, Chicago: University of Chicago Press.

McCallum, Bennett T (1988), "Robustness Properties of a Rule for Monetary Policy," Carnegie-Rochester Conference Series on Public Policy, vol. 29 (Autumn), pp. 173–203.

McCallum, Bennett T (1999), "Issues in the Design of Monetary Policy Rules," in John B. Taylor and Michael Woodford, eds., Handbook of Macroeconomics. Amsterdam: North-Holland.

Orphanides, Athanasios (2001), "Monetary policy rules, macroeconomic stability and inflation: a view from the trenches," Finance and Economics Discussion Series 2001-62, Board of Governors of the Federal Reserve System.

Orphanides, Athanasios and John C Williams (2002), "Robust Monetary Policy Rules with Unknown Natural Rates," Brookings Papers on Economic Activity, vol. 33 (2), pages 63-146.

Rangarajan, Chakravarthy (1988), "Issues in Monetary Management," Presidential Address at the Indian Economic Conference, Calcutta, December.

_______ (1997), "Dimensions of Monetary Policy," The Anantharamakrishnan Memorial Lecture, Chennai, February.

Rangarajan, Chakravarthy and R R Arif (1990), "Money, Output and Prices- A Macro Econometric Model," Economic and Political Weekly, vol.25, no.16.

Ranjan, Rajiv; Rajeev Jain and Sarat C. Dhal. (2007), "India's Potential Economic Growth: Measurement Issues and Policy Implications", Economic and Political Weekly, Vol. 42, no. 17, pp.1563-72.

Reserve Bank of India (2002), Report on Currency and Finance.

Rudebusch, Glenn (1995), “Federal Reserve Interest Rate Targeting, Rational Expectations and the Term Structure,” Journal of Monetary Economics, Vol. 24, pp.245-274.

Rudebusch, Glenn and Lars E O Svensson (1999), “Policy Rules for Inflation Targeting,” NBER Chapters in Monetary Policy Rules, pages 203-262 National Bureau of Economic Research.

Sack, Brian and Volker Wieland (1999), “Interest-Rate Smoothing and Optimal Monetary Policy: A Review of Recent Empirical Evidence,” Finance and Economics Discussion Series, 1999-39, Federal Reserve Board, (August).

Singh, Kanhaiya and Kaliappa Kalirajan (2006), “Monetary Policy in India: Objectives, Reaction and Policy Effectiveness, Review of Applied Economics, vol.2 (2), pp. 181-99.

Svensson, Lars E O (1999a), “Price Stability as a Target for Monetary Policy: Defining and Maintaining Price Stability,” NBER Working Papers 7276, National Bureau of Economic Research.

_________ (1999b), “How Should Monetary Policy be Conducted in an Era of Price Stability?” in New challenges for monetary policy, Federal Reserve Bank of Kansas City, 1999, pp. 195-259.

_________ (2003), “What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules,” Journal of Economic Literature, American Economic Association, vol. 41(2), pages 426-477.

_________ (2007), “What Have Economists Learned about Monetary Policy over the past 50 Years?” presented at the conference on ‘Monetary Policy over Fifty Years’ at Deutsche Bundesbank Frankfurt am Main, September 21.

Taylor, John B (1993), “Discretion versus Policy Rules in Practice,” Carnegie-Rochester Conference Series on Public Policy, 39, pp.195-214.

________ (1999), “A Historical Analysis of Monetary Policy Rules,” in Monetary Policy Rules. Chicago: University of Chicago Press for NBER.

________ (2000), "The Monetary Transmission Mechanism and the Evaluation of Monetary Policy Rules," Central Bank of Chile Working Papers no. 87, Central Bank of Chile.

________ (2007), "The Explanatory Power of Monetary Policy Rules," Business Economics, vol. 42(4), pages 8-15, October

________ (2008), "The Financial Crisis and the Policy Responses: An Empirical Analysis of What Went Wrong," Keynote at Bank of Canada, November 2008.

Tinbergen, Jan (1952), On the theory of economic policy, Amsterdam: North Holland.

Theil, Henry (1964), Optimal decision rules for government and industry, Amsterdam: North Holland.

Virmani, Vineet (2004), "Operationalising Taylor-type Rules for the Indian Economy: Issues and Some Results (1992Q3 2001Q4)", IIMA Working Papers with number 2004-07-04.

Walsh, Carl E (2003), "Speed Limit Policies: The Output Gap and Optimal Monetary Policy", American Economic Review, vol. 93, no. 1, pp. 265-27.

White, William R (2006), "Is price stability enough?", BIS Working Papers, no 205.

Wicksell, Knut (1898), "The Influence of the Rate of Interest on Commodity Prices," reprinted in Erik Lindahl (1958) (ed.), Selected Papers on Economic Theory by Knut Wicksell, pp. 67-92.

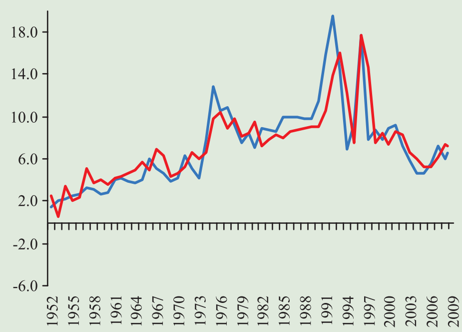
Williams, John C (1999), "Simple Rules for Monetary Policy," Finance and Economics Discussion Series, 1999-12, Federal Reserve Board, February.

Woodford, Micahel (2001), "The Taylor Rule and Optimal Monetary Policy," American Economic Review, 91(2): 232-237.

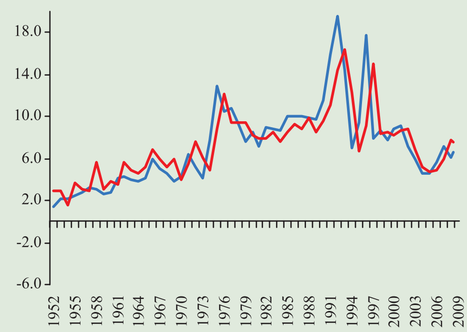
_________ (2003), "Optimal Interest-Rate Smoothing," Review of Economic Studies, vol. 70(4), pages 861-886, October.

Annex 1

Taylor Rule with Interest Rate Smoothing (OLS)

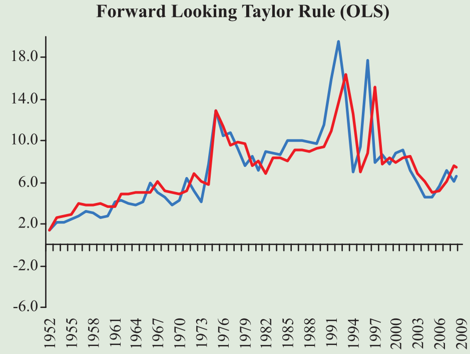


Backward Looking Taylor Rule (OLS)

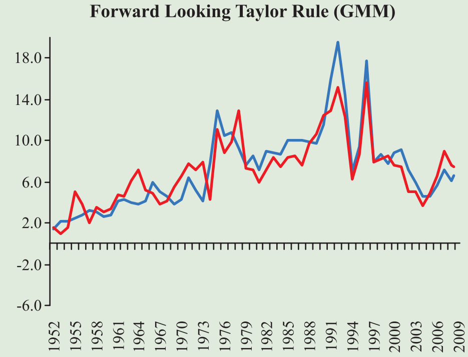


Actual nominal interest rate Taylor rule

Forward Looking Taylor Rule (OLS)



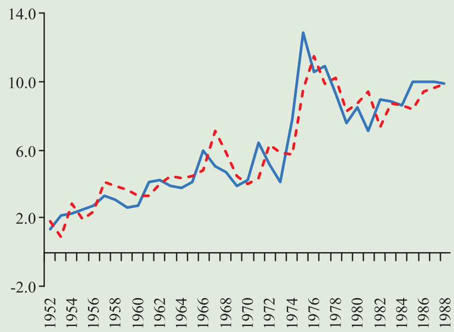
Forward Looking Taylor Rule (GMM)



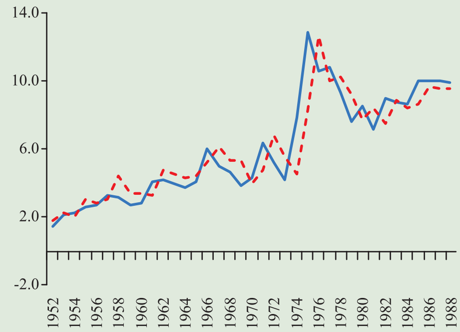
Actual nominal interest rate Taylor rule

Annex 2

Taylor Rule with Interest Rate Smoothing (OLS)

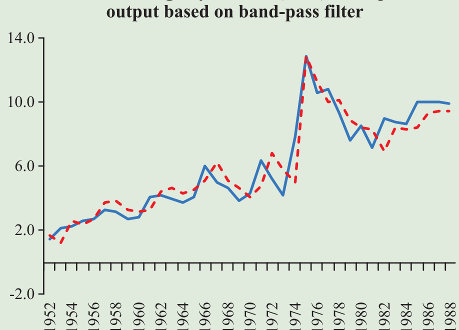


Forward Looking Taylor Rule (OLS)

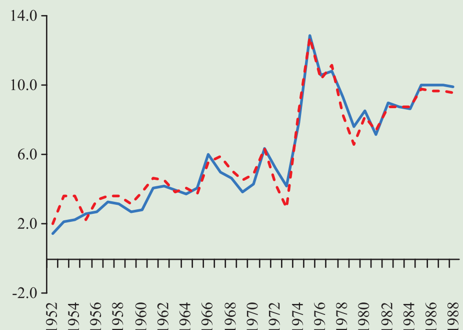


Actual nominal interest rate   Taylor rule

Backward Looking Taylor Rule (OLS)- with potential output based on band-pass filter

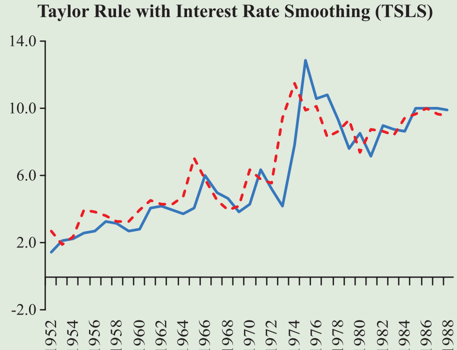


Taylor Rule with Interest Rate Smoothing (GMM)

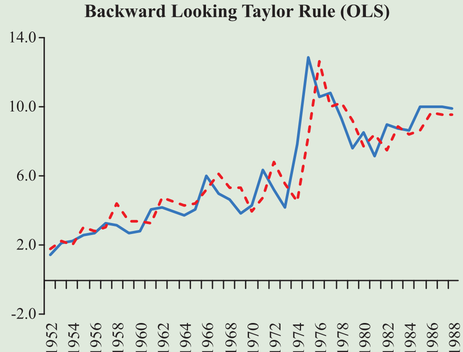


Actual nominal interest rate   Taylor rule

Taylor Rule with Interest Rate Smoothing (TSLS)



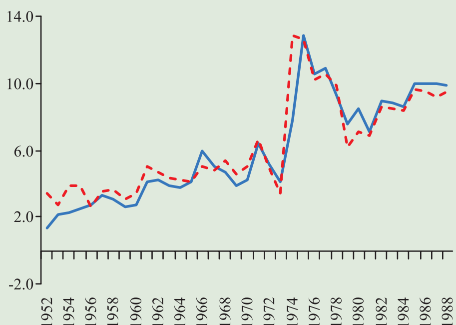
Backward Looking Taylor Rule (OLS)



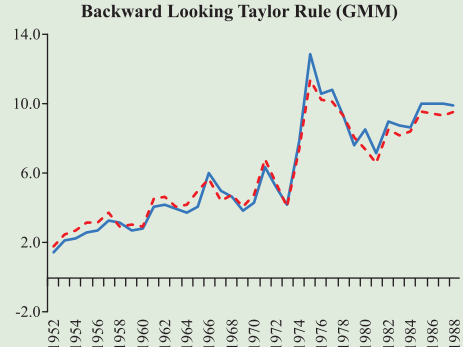
Actual nominal interest rate   Taylor rule

Annex 2

Forward Looking Taylor Rule (GMM)

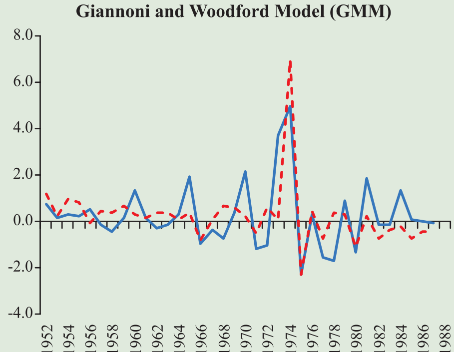


Backward Looking Taylor Rule (GMM)

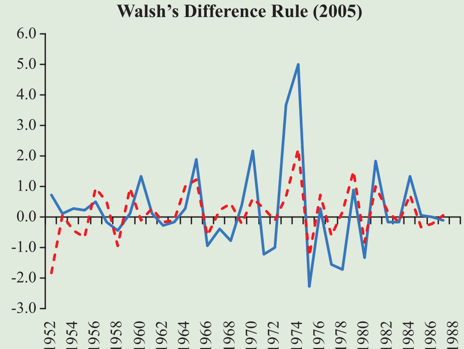


Actual nominal interest rate Taylor rule

Giannoni and Woodford Model (GMM)

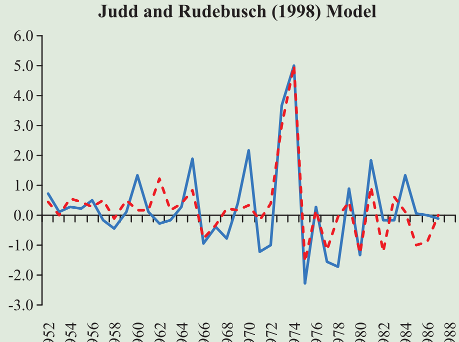


Walsh's Difference Rule (2005)

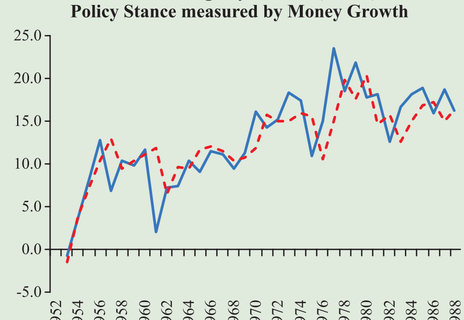


Actual nominal interest rate (first difference) Taylor rule (first difference)

Judd and Rudebusch (1998) Model

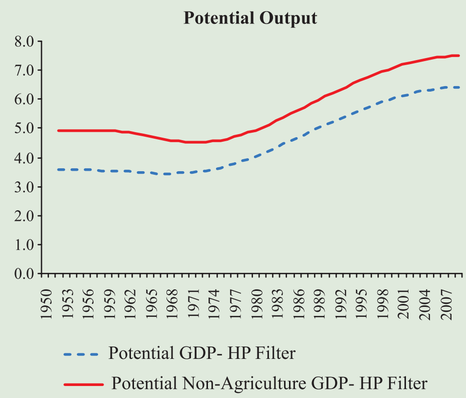


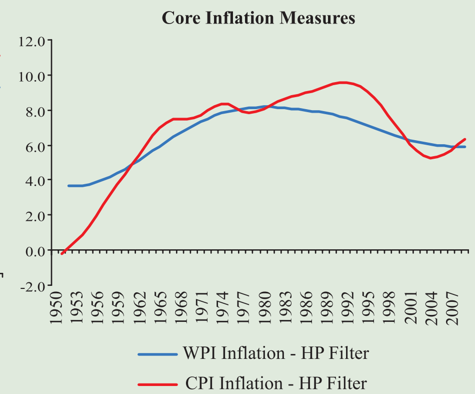
Backward Looking Taylor Rule (GMM) with Policy Stance measured by Money Growth



Actual nominal interest rate (first difference) Taylor rule (first difference)

Annex 3


Potential Output
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
Potential GDP- HP Filter
Potential Non-Agriculture GDP- HP Filter


Core Inflation Measures
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
WPI Inflation - HP Filter
CPI Inflation - HP Filter